BERMUDAGRASS (*CYNODON DACTYLON*) AND GOOSEGRASS (*ELEUSINE INDICA*) MANAGEMENT IN SEASHORE PASPALUM (*PASPALUM VAGINATUM*) TURF

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI
AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE
IN
TROPICAL PLANT AND SOIL SCIENCES

MAY 2018

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ACKNOWLEDGEMENTS

I would like to thank Dr. Zhiqiang Cheng and Dr. Joseph DeFrank for providing funding for my thesis through CTAHR's competitive Supplemental Funding Program. I would like to thank my advisor, Dr. Joseph DeFrank, for his continual support and guidance throughout the completion of my thesis. I appreciate the skills and knowledge he has taught me that will help me with my future endeavors. I would like to express my gratitude and appreciation to my committee members, Dr. Zhiqiang Cheng (co-advisor) and Dr. Orville Baldos, who were always there to help and provide valuable inputs throughout this process. I would also like to thank Craig Okazaki, Magoon Research Station supervisor, for providing research material and assisting as a graduate student and Rey Ito, The Green Doctor, for providing knowledge and valuable inputs for my thesis research. Thanks to Sean Fong, Hawaiian Turfgrass, for providing research materials; the Pali Golf Course, the Hoakalei Country Club, and the West Loch Golf Course for your cooperation and providing space for field trials; and to BASF, Bayer, and Syngenta for providing the herbicides used in this study. Lastly, I would like to thank my friends and family for all their love and support throughout this process.

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Introduction

Turfgrass areas (lawns, golf courses, athletic fields, recreation areas, etc.) have become an integral part of landscapes throughout the United States. The golf and turf industry plays an important role in Hawaii's recreational and tourism driven economy, contributing $1.4 billion in revenues (SRI International 2009).

Traditionally, most golf courses in Hawaii use a known bermudagrass hybrid (*Cynodon dactylon*) as their primary turfgrass on greens, tee boxes, fairways, and roughs. However, in recent years, a number of new golf courses in Hawaii have adopted seashore paspalum (*Paspalum vaginatum*) as their primary turfgrass and while others are replacing bermudagrass greens with seashore paspalum. This recent change in turfgrass species has been attributed to increased soil salinity. According to Duncan and Carrow (1998), major contributors to increased soil salinity include:

- Increased use of recycled water on turfgrass.
- Coastal golf course construction.
- The placement of golf courses near environmentally sensitive wetlands.
- The use of high sand root zone mixes where sands more readily become salinized than fine-textured soils.
- The emphasis on potable water conservation.
- The location of golf courses on nutrient poor sites.

Seashore paspalum has excellent tolerance to saline soils and irrigation (Lee et al. 2004). This salinity tolerance may support the use of granular salt applications to control grassy weeds in seashore paspalum (Duncan and Carrow 2000). Seashore paspalum also requires less nutrient inputs than bermudagrass (Duncan 1996). Bermudagrass does not provide acceptable turf quality when irrigated with non-potable water with high salinity resulting in an unsightly appearance (Wiecko 2003).

New management challenges emerge as more seashore paspalum golf courses are established or converted from bermudagrass. An emerging challenge of seashore paspalum establishment and maintenance is bermudagrass and goosegrass (*Eleusine indica*) contamination and infestation (Brosnan 2015). The current approach, at golf courses, to grassy weed control in seashore paspalum relies heavily on salt applications to target weeds (Kira, personal communication 2017). Brosnan et al. (2009b) found that applications of sodium chloride salt provided control of sourgrass (*Paspalum* *conjugatum*) with minimal damage to seashore paspalum turf. Sodium chloride salt applications were also applied to control goosegrass in seashore paspalum turf. Although goosegrass control was not achieved, seashore paspalum once again showed tolerance to sodium chloride salt applications (Brosnan et al. 2009a). Long-term use of salt treatments collapses soil pore space leading to a compacted soil profile with reduced water penetration and retention (Qian and Harivandi 2007). Developing new grassy weed control options that do not depend on salt applications is an important consideration on seashore paspalum golf courses to maintain healthy sustainable turf. This thesis will address Hawaii's turf and golf industry immediate need (as of 2018) for grassy weed control in seashore paspalum.

There are four main objectives to this study. The first is to identify effective means to suppress/control existing bermudagrass and goosegrass infestations within seashore paspalum turf. The second is to minimize seashore paspalum injury/discoloration and/or safen seashore paspalum to herbicide treatments. The third is to develop a best management practice to suppress/control bermudagrass and goosegrass in seashore paspalum turf based on results reported here. Lastly, provide chemical companies data for possible label changes, i.e., allow use on seashore paspalum cut below 1.3 cm.

Literature Review

Seashore paspalum is a warm-season, prostrate perennial turfgrass that is adapted to tropical, subtropical, and warm-humid regions (Duncan 1996). The grass spreads by rhizomes and stolons forming a fine-textured, dense turf with a deep root system. Seashore paspalum foliage has a shiny, waxy cuticle (Brosnan and Deputy 2008). It is adapted to high salinity soils, allowing irrigation with salt-laden water. This grass tolerates waterlogged or boggy areas and has low fertility requirements (Duncan 1996; Lee et al. 2004). The cold tolerance of seashore paspalum is similar to that of bermudagrass. However, in areas where bermudagrass does not go fully dormant and brown, but growth slows down and is semi-dormant (due to cool night temperatures), seashore paspalum is more active and maintains a greener color (Foy 2006). Seashore paspalum drought resistance is similar to centipedegrass (*Eremochloa ophiuroides*) and better than bermudagrass (Duncan and Carrow 2000). Therefore, seashore paspalum has the potential to be one of the most environmentally compatible turfgrasses in Hawaii.

In Hawaii, grassy weed infestation is the most persistent pest problem in seashore paspalum turf due to environmental conditions favoring year-round growth of weed populations (Brosnan and DeFrank 2008). Weeds in sports turf are more slippery than turfgrasses, provide poor footing compared to turfgrasses, and provide almost no resiliency or cushion for users. Furthermore, weeds lead to soil erosion, uneven playing surfaces, and require more frequent mowing (Turner 1987). Two of the most challenging weeds in seashore paspalum golf courses are bermudagrass and goosegrass (Brosnan 2015).

Bermudagrass is one of the most popular warm-season turfgrass species in the world. Bermudagrass is a perennial grass that spreads rapidly by rhizomes and stolons (Duble 2004). It is a drought resistant and relatively salt tolerant species (Etemadi et al. 2005). Bermudagrass infestation is common in seashore paspalum since they are adapted to the same environments. Several studies with herbicides have been conducted to suppress bermudagrass in other warm-season turfgrasses. Sequential applications of ethofumesate plus atrazine provided excellent control of common bermudagrass in St. Augustinegrass (*Stenotaphrum secundatum*) (McCarty 1996). However, this treatment is not useful for bermudagrass control in seashore paspalum. Atrazine is not registered for use in Hawaii and atrazine causes to excessive injury to seashore paspalum (NPIRS 2018; Yu et al. 2015). Multiple applications of fenoxaprop + triclopyr or fluazifop + triclopyr suppressed bermudagrass in zoysiagrass (*Zoysia* spp.) (McElroy and Breeden 2006). McCullough (2017) concluded that fenoxaprop, fluazifop, and triclopyr are not safe to use in seashore paspalum. Traditionally, golf courses have relied on spot treatments of glyphosate for bermudagrass control (Johnson 1988).

Currently, ethofumesate is the only selective herbicide labeled for bermudagrass suppression in seashore paspalum (Anonymous 2017a). Bermudagrass suppression is attributed to higher foliar and root absorption of ethofumesate compared to seashore paspalum (McCullough et al. 2016). Sequential applications of ethofumesate plus flurprimidol provided bermudagrass suppression in seashore paspalum turf. The timing of the applications was important in obtaining maximum bermudagrass suppression. Treatments initiated as the bermudagrass broke dormancy were more successful than treatments started when bermudagrass was actively growing. Although bermudagrass suppression was achieved, the seashore paspalum injury was considered unacceptable for practical use (Johnson and Duncan 2000). McCullough (2017) evaluated bermudagrass management with ethofumesate, fluazifop, and clethodim concluding that single herbicides or combinations have been ineffective so far and caused too much damage to the seashore paspalum.

Goosegrass is a summer annual grass that spreads by seed. The stems are often compressed, originating from a central point and the crown is white or silver in color (Bayer CropScience 2015). Goosegrass is well adapted to highly compacted soils with year round growth and seed production in tropical areas like Hawaii (Wiecko 2000). Topramezone and mesotrione are the only herbicides currently labeled for postemergence goosegrass control in seashore paspalum; however, label warnings describe persistent foliar bleaching. (Anonymous 2017b; Anonymous 2017d). Goosegrass control has been achieved in other turf species, but options are limited for seashore paspalum. In creeping bentgrass and non-overseeded bermudagrass, the best option for effective preemergence control of goosegrass on putting greens is bensulide + oxadiazon (Brosnan 2015). Selective postemergence herbicide control of goosegrass in other turf species include diclofop plus metribuzin, MSMA plus metribuzin, and foramsulfuron plus metribuzin (Nishimoto and Kawate 2003; Busey 2004). Goosegrass control in bermudagrass with minimal reduction in turf density can be achieved by the use of topramezone alone or tank mix with triclopyr, however significant turf discoloration occurs (Cox et al. 2017). The addition of chelated iron to a tank mix with topramezone provided control of goosegrass and acted as a safener to bermudagrass by reducing turf discoloration (Boyd et al. 2016a; Boyd et al. 2016b). In bermudagrass greens, the best option for goosegrass control is mechanical removal before weed populations become problematic (Brosnan 2015). Brosnan et al. (2009a) evaluated sodium chloride applications as an alternative to herbicide control of goosegrass in seashore paspalum turf. However, sequential granular applications of sodium chloride did not effectively control goosegrass in the study.

One of the major problems for weed control in seashore paspalum turf is sensitive to many herbicides commonly used on other turfgrasses in Hawaii. Furthermore, many herbicides labeled for use on bermudagrass are not available for use on seashore paspalum (Brosnan and Deputy 2008). According to National Pesticide Information Retrieval System (NPIRS 2018), 36 pesticides (sorted by common chemical name) are registered for use in seashore paspalum in Hawaii (Table 1).

Studies have been conducted to evaluate the tolerance of seashore paspalum to several preemergence and postemergence herbicides. Johnson and Duncan (1997) evaluated the tolerance of four seashore paspalum cultivars (AP 10, HI 25, PI 28960, and K-7) to the recommended rates and 3 times the recommended rates of diclofop, quinclorac, dicamba, imazaquin, MON 12000, and 2,4-D plus mecoprop plus dicamba. The conclusion from this study was quinclorac, dicamba, and MON 12000 were safe on the cultivars used in the study, diclofop, and imazaquin were marginal, and 2,4-D plus mecoprop plus dicamba were not safe.

In 2006, Unruh et al. tested the tolerance of seashore paspalum (‘Salam’) to postemergence herbicides. Herbicides were selected based on registered uses on other turfgrass species for the control of grassy weeds (clethodim, ethofumesate, metsulfuron, sethoxydim, and quinclorac), broadleaf weeds (clopyralid, dicamba, and mecoprop plus 2,4-D plus dicamba) and sedges (bentazon, halosulfuron, imazapic, imazaquin and trifloxysulfuron-sodium). At the product labeled recommended rates, metsulfuron, quinclorac, clopyralid, dicamba, mecoprop plus 2,4-D plus dicamba, bentazon, halosulfuron, and imazaquin are considered safe to apply to seashore paspalum. Clethodim, sethoxydim, ethofumesate, imazapic, and trifloxysulfuron-sodium caused greater than the acceptable injury and are considered not safe for use in seashore paspalum.

Patton et al. (2009) evaluated the tolerance seashore paspalum (‘SeaSpray’) seedlings to various preemergence and postemergence herbicides. Application of herbicides were applied two weeks after emergence and herbicide injury was rated. The overall conclusion of the study was clopyralid, halosulfuron, metsulfuron, quinclorac, carfentrazone, salt-water treatment, and metconazole can be applied to ‘Sea Spray’ seedlings 2 weeks after seedling emergence. Sulfentrazone, fluroxypyr, 2,4-D + MCPP + dicamba + carfentrazone, 2,4-D + MCPP + dicamba, MCPP + 2,4-D +dicamba, sulfosulfuron, pronamide, oxadiazon, pendimethalin, dithiopyr, and prodiamine can be applied to seedlings at least one month after emergence. Herbicides not safe to use on seedlings include MSMA, imazaquin, siduron, triclopyr, fluazifop-P-butyl, fenoxaprop-ethyl, bispyribac-sodium, and ethofumesate.

Duncan and Carrow (2000) summarized the herbicides safety on seashore paspalum turf. Preemergence herbicides that are non-injurious to seashore paspalum include bensulide, pronamide, benefin, DCPA, granular oxadiazon, and pendimethalin. Non-injurious postemergence herbicides include benefin, ethofumesate, quinclorac, MCPP + 2,4-D + dicamba, dithiopyr, dicamba, pendimethalin, MCPP, Pronamide, isoxaben, halosulfuron, mecoprop, and bensulide. Preemergence herbicides that are phytotoxic to seashore paspalum include oxadiazon WP, oryzalin, and diclofop. Postemergence herbicides that cause injury include metribuzin, simazine, fenoxaprop, fluazifop, triclopyr, triclopyr + clopyralid, and imazaquin.

In Hawaii, a tank mix of ethofumesate, metribuzin, mesotrione, and topramezone provided a high level of zoysiagrass (*Zoysia* spp. ‘Emerald’ and ‘Zenith’) suppression in bermudagrass (‘TifGrand’) turf (Ito, personal communication 2016). After applying this mix to the bermudagrass, the left over tank mix was applied to a mix stand of bermudagrass (‘Tifway 419’), seashore paspalum (‘SeaIsle 2000 SP’) and zoysiagrass (‘Emerald’). It was concluded that seashore paspalum had a higher tolerance to the spray mix compared to the bermudagrass and zoysiagrass. This observation served as the basis for the evaluation of various tank mixes for bermudagrass and goosegrass control in seashore paspalum turf.

Ethofumesate is a preemergence and postemergence herbicide used for the control and/or suppression of specific annual grasses and broadleaf weeds. Ethofumesate is a group 16 herbicide (mode of action is unknown) (Anonymous 2017a). Susceptible weeds absorb ethofumesate through foliar contact and root absorption (McCullough et al. 2016). Ethofumesate is moderately water-soluble, does not dissociate, and has a moderate leaching potential (Table 2) (Lewis et al. 2016). Ethofumesate is labeled for use on ornamental turf sites such as golf courses, sod farms, cemeteries, and lawns. Ethofumesate can be applied to seashore paspalum for bermudagrass suppression (Anonymous 2017a).

Metribuzin is a selective herbicide used for the control of grasses and broadleaf weeds. Metribuzin is a group 5 herbicide (photosystem II inhibitor) (Anonymous 2017c). Metribuzin is mainly absorbed by the roots and by the leaves to a lesser extent. Photosystem II inhibitors disrupt the electron transfer in photosynthesis (AgChem Access 2015). Photosystem II inhibitors halt electron flow within the photosynthetic electron transport chain, which leads to increased oxidative stress (Abendroth et al. 2006). Inhibiting photosynthesis can result in stunted plant growth and slow death due to lack of essential plant metabolites. However, more rapid plant death normally occurs from the production of secondary toxic substances (Gunsolus and Curran 2002). Metribuzin is highly water-soluble, a strong acid (low dissociation constant), and has a moderate leaching potential (Table 2) (Lewis et al. 2016). Metribuzin is labeled for use on established bermudagrass turf sites such as parks, athletic fields, and golf course fairways, but not on greens, tees, or aprons. Metribuzin is not labeled for use in seashore paspalum (Anonymous 2017c) as of May 2018.

Mesotrione is a systemic preemergence and postemergence herbicide used for selective control of weeds in turfgrasses. Mesotrione is a group 27 herbicide (HPPD inhibitor) (Anonymous 2017d). Mesotrione inhibits carotenoid biosynthesis by inhibiting the enzyme HPPD (Abendroth et al. 2006). Susceptible weeds absorb mesotrione through foliar contact and soil absorption. Foliage of susceptible weeds turns white (loss of chlorophyll) and death may take up to three weeks (Anonymous 2017d). The addition of a photosystem II inhibitor, such as metribuzin, to a tank mixture with an HPPD inhibitor herbicide has resulted in increased weed control likely due complementary mode of actions or synergism (Armel et al. 2005). Mesotrione is highly water-soluble, a weak acid (moderate dissociation constant), and has a moderate leaching potential (Table 2) (Lewis et al. 2016). Mesotrione is labeled for use in non-crop areas, sod farms, athletic fields, parks, lawns, and golf courses, but not golf course greens. Application to seashore paspalum can be made if injury or removal can be tolerated (Anonymous 2017d).

Topramezone is a postemergence herbicide used for selective control of broadleaf and grass weeds in select turfgrass species. Topramezone is a group 27 herbicide (HPPD inhibitor). HPPD inhibitors work by inhibiting the HPPD enzyme, which results in carotenoid biosynthesis inhibition (Abendroth et al. 2006). Susceptible weeds absorb topramezone through leaves, roots, and shoots and is translocated to the apical growing points. After application, new foliage turns white due to loss of chlorophyll and becomes necrotic (Anonymous 2017b). The addition of a photosystem II inhibitor, such as metribuzin, to a tank mixture with an HPPD inhibitor herbicide has resulted in increased weed control likely due complementary mode of actions or synergism (Armel et al. 2005). Topramezone is highly water-soluble, a weak acid (moderate dissociation constant), and has a very high leaching potential (Table 2) (Lewis et al. 2016). The herbicide is labeled for use in residential and nonresidential turfgrass including athletic fields, golf courses, roadsides, and sod farms. To control goosegrass, a single application of topramezone can be made to seashore paspalum with the expectation of persistent turf discoloration (Anonymous 2017b).

Tables

Table 1. Pesticide common chemical names labeled for use in seashore paspalum (*Paspalum vaginatum*). Information taken from National Pesticide Informational Retrieval System (NPIRS 2018).

Number of Products and Common Chemical Name	Preemergence Herbicide	Postemergence Herbicide	Insecticide	Fungicide
2 Acetic acid, (2,4-dichlorophenoxy)-, 2-ethylhexyl ester		X		
1 * Bifenthrin			X	
1 * Borax (B4Na2O7.10H2O)			X	
4 Carfentrazone-ethyl		X		
1 Chlorothalonil				X
1 * Clopyralid		X		
1 * Clopyralid, monoethanolamine salt		X		
3 Dicamba		X		
4 Dicamba, dimethylamine salt		X		
4 Dimethylamine 2,4-dichlorophenoxyacetate		X		
7 * Dithiopyr	X			
2 * Ethofumesate	X	X		
1 * Flazasulfuron	X	X		
1 * Flumioxazin	X	X		
4 * Flurprimidol		X		
5 * Halosulfuron-methyl		X		
1 Imazethapyr	X	X		
1 * Indaziflam	X			
1 Isoxaben	X			
1 MCPA, 2-ethylhexyl ester		X		
3 Mecoprop-P		X		
1 Mecoprop-P-dimethylammonium		X		
1 * Metconazole				X
1 * Metsulfuron-methyl		X		
4 * Oxadiazon	X			
2 * Pendimethalin	X			
6 * Penoxsulam		X		
25 * Prodiamine	X			
1 Pyraclostrobin				X
1 * Sodium bentazon		X		
9 * Sulfentrazone		X		
1 * 1H-1,2,4-Triazole-1-ethanol, .alpha.-(2-(4-chlorophenyl)ethyl				X
4 * Trinexapac-ethyl		X		
5 * Triticonazole				X
2 * Zeta-Cypermethrin			X	
2 * dimethenamid-P	X			

* Chemical is sole active ingredient in at least one product.

Table 2. Water solubility, dissociation constant, and GUS leaching potential of ethofumesate, mesotrione, metribuzin, and topramezone. Information taken from the Pesticide Properties DataBase (Lewis et al. 2016).

Common Name	Trade Name	Water Solubility (mg l^{-1})	Dissociation constant (pKa) at 25ºC	GUS leaching potential index
Ethofumesate	Prograss® SC	50 - Moderate	N/A – No dissociation	2.57 - Moderate
Mesotrione	Tenacity®	1500 - High	3.12 – Weak acid	2.69 - Moderate
Metribuzin	Sencor® DF	1165 - High	0.99 – Strong acid	2.57 - Moderate
Topramezone	Pylex™	100000 – High	4.06 – Weak acid	4.75 – Very High

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Anonymous. 2017c. Sencor® DF 75% dry flowable herbicide product label. Bayer CropScience LP, Environmental Science Division. Research Triangle Park, NC.

Anonymous. 2017d. Tenacity® herbicide product label. Syngenta Crop Protection, LLC. Greensboro, NC.

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Chapter 2. Bermudagrass (*Cynodon* spp.) and goosegrass (*Eleusine indica*) management in seashore paspalum (*Paspalum vaginatum*) turf

Abstract

Seashore paspalum (*Paspalum vaginatum*) has seen increased popularity in Hawaii due to use of non-potable water on various sports venues. Bermudagrass (*Cynodon dactylon*) and goosegrass (*Eleusine indica*) are problem weeds infesting both fairways and greens in many seashore paspalum golf courses. Herbicide efficacy studies were conducted at the Pali Golf Course (‘Salam’, greens cut), the Hoakalei Country Club (‘SeaDwarf’, fairway cut), the West Loch Golf Course (‘Salam’, greens cut), and the Magoon Research Station (‘SeaStar’, grown in container). The herbicides metribuzin, topramezone, mesotrione, and ethofumesate were evaluated alone and in tank mixtures for bermudagrass and goosegrass control and seashore paspalum injury. At the Pali Golf Course, maximum goosegrass control was obtained with topramezone (0.012 kg ai/ha) + metribuzin (0.11 kg ai/ha) in tank mix. However, seashore paspalum injury was severe. At the Hoakalei Country Club, maximum bermudagrass injury with minimal seashore paspalum injury was obtained with tank mixes of mesotrione (0.070 kg ai/ha) + metribuzin (0.21 kg ai/ha) + ethofumesate (1.12 kg ai/ha) and topramezone (0.025 kg ai/ha) + metribuzin (0.21 kg ai/ha) + ethofumesate (1.12 kg ai/ha). Unacceptable turf injury was obtained in all treatments that did not include metribuzin. Although tank mixes provided acceptable seashore paspalum turf discoloration, long-term suppression of bermudagrass was not obtained. At the West Loch Golf Course, goosegrass was controlled with tank mixes that included topramezone (0.012 kg ai/ha) + metribuzin (0.11 kg ai/ha) with an acceptable level of seashore paspalum discoloration. Incorporating a post-spray dry down allowed for complete control of goosegrass with one spray application. Maximum bermudagrass injury was seen in treatments with mesotrione and/or ethofumesate. At the Magoon Research Station, maximum selective bermudagrass suppression was achieved with tank mixes of topramezone (0.012 kg ai/ha) + ethofumesate (1.12 kg ai/ha) and topramezone (0.012 kg ai/ha) + metribuzin (0.11 kg ai/ha) + ethofumesate (1.12 kg ai/ha). A major finding throughout all trials was seashore paspalum turf bleaching from mesotrione and topramezone can be reduced with the addition of metribuzin and/or ethofumesate to tank mix. Overall, tank mixes of mesotrione, topramezone, metribuzin, and ethofumesate have the potential for postemergence goosegrass control and bermudagrass suppression in seashore paspalum turf.

Introduction

Turfgrass areas (lawns, golf courses, athletic fields, recreation areas, etc.) have become an integral part of landscapes throughout the United States. The golf and turf industry plays an important role in Hawaii's recreational and tourism driven economy, contributing $1.4 billion in revenues (SRI International 2009).

Traditionally, most golf courses in Hawaii use a known bermudagrass hybrid (*Cynodon dactylon*) as their primary turfgrass on greens, tee boxes, fairways, and roughs. However, in recent years, a number of new golf courses in Hawaii have adopted seashore paspalum (*Paspalum vaginatum*) as their primary turfgrass and while others are replacing bermudagrass greens with seashore paspalum. This recent change in turfgrass species has been attributed to increased soil salinity. According to Duncan and Carrow (1998), increased use of recycled water on turfgrass and emphasis on potable water conservation are major contributors to increased soil salinity. Seashore paspalum has excellent tolerance to saline soils and irrigation (Lee et al. 2004). This salinity tolerance may support the use of granular salt applications to control grassy weeds in seashore paspalum (Duncan and Carrow 2000). Bermudagrass does not provide acceptable turf quality when irrigated with non-potable water with high salinity resulting in an unsightly appearance. (Wiecko 2003).

New management challenges emerge as more seashore paspalum golf courses are established or converted from bermudagrass. An emerging challenge of seashore paspalum establishment and maintenance is bermudagrass and goosegrass (*Eleusine indica*) contamination and infestation (Brosnan 2015). Traditionally, golf courses have relied on spot treatments of glyphosate for bermudagrass control (Johnson 1988). The current approach, at golf courses, to grassy weed control in seashore paspalum relies heavily on salt applications to target weeds. Brosnan et al. (2009b) found that applications of sodium chloride salt provided control of sourgrass (*Paspalum conjugatum*) with minimal damage to seashore paspalum turf. Sodium chloride salt applications were also applied to control goosegrass in seashore paspalum turf. Although goosegrass control was not achieved, seashore paspalum once again showed tolerance to sodium chloride salt applications (Brosnan et al. 2009a). Long-term use of salt treatments collapses soil pore space leading to a compacted soil profile with reduced water penetration and retention (Qian and Harivandi 2007). Developing new grassy weed control options that do not depend on salt applications is an important consideration on seashore paspalum golf courses. This thesis will address Hawaii's turf and golf industry immediate need (as of 2018) for grassy weed control in seashore paspalum.

Currently, ethofumesate is the only selective herbicide labeled for bermudagrass suppression in seashore paspalum (Anonymous 2017a). Bermudagrass suppression is attributed to higher foliar and root absorption of ethofumesate compared to seashore paspalum (McCullough et al. 2016). Sequential applications of ethofumesate plus flurprimidol provided bermudagrass suppression in seashore paspalum turf. The timing of the applications was important in obtaining maximum bermudagrass suppression. Treatments initiated as the bermudagrass broke dormancy were more successful than treatments started when bermudagrass was actively growing. Although bermudagrass suppression was achieved, the seashore paspalum injury was considered unacceptable for practical use (Johnson and Duncan 2000). McCullough (2017) evaluated bermudagrass management with ethofumesate, fluazifop, and clethodim concluding that single herbicides or combinations have been ineffective so far and caused too much damage to the seashore paspalum.

Topramezone and mesotrione are the only herbicides currently labeled for postemergence goosegrass control in seashore paspalum; however, label warnings describe foliar bleaching. (Anonymous 2017b; Anonymous 2017d). Goosegrass control has been achieved in other warm season turf, but options are limited for seashore paspalum. Selective postemergence herbicide control of goosegrass in other warm season turf include diclofop plus metribuzin, MSMA plus metribuzin, and foramsulfuron plus metribuzin (Nishimoto and Kawate 2003; Busey 2004). Goosegrass control in bermudagrass with minimal reduction in turf density can be achieved by the use of topramezone alone or tank mix with triclopyr, however significant turf discoloration occurs (Cox et al. 2017). The addition of chelated iron to a tank mix with topramezone provided control of goosegrass and acted as a safener to bermudagrass by reducing turf discoloration (Boyd et al. 2016a; Boyd et al. 2016b). A major problem for weed control in seashore paspalum turf is sensitivity to many herbicides commonly used on other turfgrasses in Hawaii. Furthermore, many herbicides labeled for use on bermudagrass are not available for use on seashore paspalum (Brosnan and Deputy 2008).

In Hawaii, a tank mix of ethofumesate, metribuzin, mesotrione, and topramezone provided a high level of zoysiagrass (*Zoysia* spp. ‘Emerald’ and ‘Zenith’) suppression in bermudagrass (‘TifGrand’) turf (Ito, personal communication 2016). After applying this mix to the bermudagrass, the left over tank mix was applied to a mix stand of bermudagrass (‘Tifway 419’), seashore paspalum (‘SeaIsle 2000 SP’) and zoysiagrass (‘Emerald’). It was concluded that seashore paspalum had a higher tolerance to the spray mix compared to the bermudagrass and zoysiagrass. This observation served as the basis for the evaluation of various tank mixes for bermudagrass and goosegrass control in seashore paspalum turf.

There are four main objectives to this study. The first is to identify effective means to suppress/control existing bermudagrass and goosegrass infestations within seashore paspalum turf. The second is to minimize seashore paspalum injury/discoloration and/or safen seashore paspalum to herbicide treatments. The third is to develop a best management practice to suppress/control bermudagrass and goosegrass in seashore paspalum turf based on results reported here. Lastly, provide chemical companies data for possible label changes, i.e., allow use on seashore paspalum cut below 1.3 cm.

Materials and Methods

Experiment 1. Seashore paspalum and goosegrass response to mesotrione, metribuzin, and topramezone single product and tank mixes at Pali Golf Course.

This experiment was conducted on a 'Salam' seashore paspalum green infested with goosegrass at Pali Golf Course (Kaneohe, HI) in April 2016. Seashore paspalum turfgrass at this site was established on a Kaneohe silty clay soil (very-fine, ferruginous, isohyperthermic Rhodic Acrudox). Herbicide spray treatments (Table 3) were applied using a 3-nozzle boom (nozzles spaced 50.8 cm apart) fitted with three TeeJet 8004 LP nozzle tips (Spraying Systems Co., Wheaton IL). Each treatment plot measured 1.83 m wide by 3.05 m long. The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 374.2 liters per hectare at 131 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Herbicides were applied on 04/06/16 and 04/20/16.

The experimental design was a randomized complete block with 4 replications. Visual ratings of green color (0 = brown/white to 100 = maximum attainable green color) were recorded for seashore paspalum and goosegrass. Commercially acceptable green color ratings is 85% and above for seashore paspalum turf. Rating dates included 04/13/16, 04/19/16, 04/28/16, 05/4/16, and 05/11/16. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings. Herbicide treatment means were separated using Tukey's mean testing.

Experiment 2. Seashore paspalum and bermudagrass response to ethofumesate in combination with metribuzin, mesotrione, and topramezone at Hoakalei Country Club.

Studies were conducted on a 'SeaDwarf' seashore paspalum driving range, maintained at a fairway cut, infested with bermudagrass at Hoakalei Country Club (Ewa Beach, HI) in December 2016 and June 2017. Seashore paspalum turfgrass at this site was established on a coral outcrop soil

(Coarse-loamy, mixed, semiactive, frigid Argic Endoaquods). Herbicide treatments (Table 4) were applied using a single nozzle boom fitted with a TeeJet AI 9508 E nozzle tip (Spraying Systems Co., Wheaton, IL). Each treatment plot measured was 0.91 m wide by 4.57 m long, with a 0.30 m buffer zone between treatments (Figure 1). The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 411.6 liters per hectare at 206.8 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Trial 1 application dates were 12/21/16 and 01/31/17 (41 days apart). Trial 2 application dates were 06/20/17 and 08/01/17 (42 days apart). Trial starting dates were selected to represent the start of winter and summer seasons in Hawaii, Trial 1 and 2 respectively.

The experimental design was a split-plot with 4 replications. Trial run was the main factor with herbicide treatment as the sub-factor. Visual ratings of green color (0 = brown/white to 100 = maximum attainable green color) were recorded for seashore paspalum and bermudagrass. Commercially acceptable green color ratings is 85% and above for seashore paspalum turf. Trial 1 rating dates were 12/30/16, 01/11/17, 01/31/17, 02/14/17, and 03/07/17. Trial 2 rating dates were 06/27/17, 07/11/17, 07/25/17, 08/15/17, and 08/23/17. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings. Means were separated using Tukey's mean testing.

Experiment 3. Seashore paspalum, bermudagrass, and goosegrass response to tank mixes and split applications of ethofumesate, metribuzin, mesotrione, and topramezone at West Loch Golf Course.

Studies were conducted on a 'Salam' seashore paspalum green infested with bermudagrass and goosegrass at West Loch Golf Course (Ewa Beach, HI) in February 2017 and March 2017. Seashore paspalum turfgrass at this site was established on a Helemano silty clay (Very-fine, kaolinitic, isohyperthermic Rhodic Eutrustox) and Keaau clay, saline soil (Very-fine, smectitic, calcareous, isohyperthermic Cumulic Vertic Endoaquolls). Herbicide treatments (Table 5) were applied using a single nozzle boom fitted with a TeeJet AI 9508 E nozzle tip (Spraying Systems Co., Wheaton, IL). Each treatment plot measured was 0.91 m wide by 6.07 m long, with a 0.30 m buffer zone between treatments. The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 411.6 liters per hectare at 206.8 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Trial 1 application dates were 02/14/17, 02/28/17, 03/23/17 and 04/06/17. Trial 2 application dates were 03/07/17, 03/21/17, 04/20/17, and 05/04/17. No irrigation was applied for 16 days following the initial herbicide treatments in trial 1, an unintentional stoppage due to failure in automated irrigation system. Trial 2 received regular irrigation (i.e., irrigation amount and frequency consistent with commercial greens appearance and usage) throughout the experiment.

The experimental design was a split-plot with 4 replications. Trial run was the main factor with herbicide treatment as the sub-factor. Visual ratings of green color (0 = brown/white to 100 = maximum attainable green color) were recorded for seashore paspalum, bermudagrass and goosegrass. Commercially acceptable green color ratings is 85% and above for seashore paspalum turf. Final goosegrass counts and percent control (0 = no control to 100 = complete control/all dead) were also recorded. Trial 1 rating dates were 02/21/17, 02/28/17, 03/07/17, 03/14/17, 03/21/17, 03/28/17, 04/06/17, and 04/20/17. Trial 2 rating dates were 03/14/17, 03/21/17, 03/28/17, 04/06/17, 04/20/17, 04/27/17, 05/04/17, 05/18/17. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings, percent control of goosegrass, and final goosegrass counts. Means were separated using Tukey's mean testing.

Experiment 4. Seashore paspalum response to mesotrione, and topramezone alone and in tank mix with ethofumesate and metribuzin at Hoakalei Country Club.

Experiment conducted on a 'SeaDwarf' seashore paspalum driving range, maintained at a fairway cut, at Hoakalei Country Club (Ewa Beach, HI) in August 2017. Seashore paspalum turfgrass at this site was established on a coral outcrop soil (Coarse-loamy, mixed, semiactive, frigid Argic Endoaquods). Herbicide treatments (Table 6) were applied using a single nozzle boom fitted with a TeeJet AI 9508 E nozzle tip (Spraying Systems Co., Wheaton, IL). Each treatment plot measured was 0.91 m wide by 4.57 m long, with a 0.30 m buffer zone between treatments. The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 411.6 liters per hectare at 206.8 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Herbicides were applied on 08/01/17.

The experimental design was a randomized complete block with 4 replications. Visual ratings of green color (0 = brown/white to 100 = maximum attainable green color) were recorded for seashore paspalum. Commercially acceptable green color ratings is 85% and above for seashore paspalum turf. Rating dates included 08/08/17, 08/15/17, and 08/23/17. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings. Herbicide treatment means were separated using Tukey's mean testing.

Experiment 5. Container grown seashore paspalum and bermudagrass response to ethofumesate, metribuzin, mesotrione, and topramezone alone and in tank mixes at Magoon Research Station.

Studies were conducted on ‘SeaStar’ seashore paspalum and common bermudagrass at Magoon Research facility (Honolulu, HI) in September 2017 and October 2017. Seashore paspalum (‘SeaStar’) was obtained from Hawaiian Turf Grass (Mililani, HI). Common bermudagrass was collected from a known stand at Honolulu residence with GPS values of Latitude: 21.351055| Longitude: -157.918806. Bermudagrass turfgrass at this site was established on a rock land soil (Fine-loamy, mixed, active, frigid Typic Eutrudepts). Two sprigs of seashore paspalum and bermudagrass were planted in separate 1.642 L containers (TP49 Short One Mini-Treepots™, Stuewe & Sons, Inc.) filled with 1.56 L of growing media. Growing media was prepared by mixing 30 L of Pro-Mix BX Mycorrhizae (Premier Tech Horticulture), 15 L of silica sand, and 300 g of Osmocote® (14-14-14). Each pot received 52.1 ml of water 3 times a day from overhead irrigation. Turf received 100 ml per pot of micromax liquid fertilizer (44.8 kg/ha of nitrogen, Gaviota™ Foliar 60 19-19-19) every two weeks. Turf was clipped every two weeks with a cordless lithium 2-n-1 garden shear/shrubber combo (Black+Decker Inc.) and was grown until the container was completely filled in (Figure 2). Trial 1 was planted on 05/18/17. Trial 2 was planted on 07/13/17.

Herbicide treatments (Table 7) were applied using a single nozzle boom fitted with a TeeJet AI 9508 E nozzle tip (Spraying Systems Co., Wheaton, IL). The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 411.6 liters per hectare at 206.8 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Spray treatments applied in a shrouded box to prevent drift and maintain boom height above turf containers (Figure 3). Trial 1 application date was 09/29/17 (134 days of growth prior to herbicide application). Trial 2 application date was 10/13/17 (92 days of growth prior to herbicide application). One hour after herbicide treatments were applied the automatic overhead irrigation turned on in trial 1. Trial 2 had the irrigation was turned off for one day following herbicide application. The irrigation cycle that occurred on the same day as herbicide application (Trial 1) was made in error.

The experimental design was a split-plot 2-way factorial with 4 replications. Trial run was the main factor with species and herbicide treatment as sub-factors (Appendix). Visual ratings of green color (0 = brown/white to 100 = maximum attainable green color) and dry weights of clippings, shoots (above ground biomass), and roots were recorded for seashore paspalum, and bermudagrass. Commercially acceptable green color ratings is 85% and above for seashore paspalum turf. Trial 1 green color rating dates were 10/06/17, 10/13/17, 10/20/17, and 10/27/17. Trial 2 green color rating dates were 10/20/17, 10/27/17, 11/03/17, and 11/10/17. Clippings were collected on 09/28/17, 10/20/17/ and 11/10/17 for trial 1 and on 10/12/17, 11/03/17, and 11/24/17 for trial 2. Initial clippings (Trial 1 = 09/28/17, Trial 2 = 10/12/17) were collected before herbicide application and used for means adjustments within analysis of covariance (Figure 4). Turf was clipped using a cordless lithium 2-n-1 garden shear/shrubber combo (Black+Decker Inc.). The roots and shoots were collected on 11/27/17 for trial 1 and 12/11/17 for trial 2. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings and dry weights of shoots and roots. Analysis of covariance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on dry weights of clippings using the initial (pre-spray) clippings as the covariant. Means were separated using Tukey's mean testing.

Experiment 6. Seashore paspalum, bermudagrass, and goosegrass response to sequential tank mixes of ethofumesate, metribuzin, mesotrione, and topramezone followed by multiple applications of oxadiazon alone and in prepackaged mixture with bensulide at West Loch Golf Course.

Experiment conducted on a 'Salam' seashore paspalum green infested with Bermudagrass and goosegrass at West Loch Golf Course (Ewa Beach, HI) in July 2017. Seashore paspalum turfgrass at this site was established on a Helemano silty clay (Very-fine, kaolinitic, isohyperthermic Rhodic Eutrustox) and Keaau clay, saline soil (Very-fine, smectitic, calcareous, isohyperthermic Cumulic Vertic Endoaquolls). Herbicide treatments (Table 8) were applied using a single nozzle boom fitted with a TeeJet AI 9508 E nozzle tip (Spraying Systems Co., Wheaton, IL). Each treatment plot measured was 0.91 m wide by 2.44 m long, with a 0.30 m buffer zone between postemergence treatments. The herbicides were prepared in 3-liter plastic bottles and applied with a backpack sprayer calibrated to apply 411.6 liters per hectare at 206.8 kPa. The spray system was rinsed with water between treatments to ensure no cross contamination. Herbicide application dates included 07/11/17, 07/25/17, 08/01/17, and 08/08/17. On 08/01/17 and 08/08/17, irrigation was turned on for 10 minutes immediately after the peemergence herbicide application to remove chemicals from turf foliage and minimize turf injury.

The experimental design was a strip-plot with 4 replications. Postemergence herbicide treatment was the vertical factor and preemergence herbicide treatment was the horizontal factor. Visual ratings of green color (0 = brown to 100 = maximum attainable green color) were recorded for seashore paspalum, bermudagrass and goosegrass. Commercially acceptable green color ratings is

85% and above for seashore paspalum turf. Initial and final counts of goosegrass and percent of seashore paspalum covering the plot (0 = no grass present to 100 = plot completely filled in) were also recorded. Analysis of variance using the statistical software Statistix® 10.0 (Analytical Software, Tallahassee, FL) was performed on green color ratings, goosegrass counts, and percent of seashore paspalum covering the plot. Herbicide treatment means were separated using Tukey's mean testing.

Results

Experiment 1. Seashore paspalum and goosegrass response to mesotrione, metribuzin, and topramezone single product and tank mixes at Pali Golf Course.

<u>Seashore paspalum green color ratings</u>

The results indicate a significant herbicide treatment effect ($P<0.05$) on seashore paspalum green color ratings (Table 9). At 7DAS01, all treatments resulted in significant seashore paspalum discoloration, with treatment 3 being the most severe. Treatment 2 had the highest green color rating, which was significantly higher than all other treatments. The addition of metribuzin to mesotrione or topramezone significantly increased seashore paspalum green color ratings (Figure 5). Results were similar at 13DAS01 and all treatments had an increase in seashore paspalum green color ratings except for treatment 3. Once again, the addition of metribuzin to mesotrione or topramezone resulted in significantly higher seashore paspalum green color ratings. At 7DAS02, all herbicide treatments showed significant turf discoloration except treatment 3, which not receive a second spray application due to excessive seashore paspalum injury after the first spray application. Excessive seashore paspalum discoloration was seen in treatment 4 and treatment 5 (Figure 6). The addition of metribuzin to mesotrione increased seashore paspalum green color ratings. At 14DAS02, maximum green color ratings increased for all treatments. Treatment 4 and treatment 5 still showed significant turf discoloration, all other treatments recovered to an acceptable green color level. At 21DAS02, all treatments recovered to an acceptable green color level with treatment 4 and treatment 5 still showing slight turf discoloration.

<u>Goosegrass green color ratings</u>

The results indicate a significant herbicide treatment effect ($P<0.05$) on goosegrass green color ratings (Table 10). At 7DAS01, treatment 1 and treatment 3 had significantly lower goosegrass green color ratings compared to the other treatments. At 13DAS01, treatment 1 and treatment 2 had significantly higher goosegrass green color ratings compared to the other treatments. Treatments that included topramezone decreased goosegrass green color. No goosegrass control was recorded after first spray application. 7DAS02, all treatments decreased goosegrass green color ratings compared to 13DAS01, except for treatment 3. Treatment 3 did not receive a second application. Goosegrass percent green color was 0% for treatment 4 and treatment 5 (Figure 7), indicating complete kill. Both14DAS02 and 21DAS02 ratings recorded similar results. Goosegrass treated with treatment 4 or treatment 5 had a 0% green color rating, while goosegrass in the other treatments recovered to pre-spray condition. Only treatments with topramezone + metribuzin provided goosegrass control.

Experiment 2. Seashore paspalum and bermudagrass response to ethofumesate in combination with metribuzin, mesotrione, and topramezone at Hoakalei Country Club.

Seashore paspalum green color ratings

The results indicate a significant interaction between trial run and herbicide treatment effect ($P<0.05$) on seashore paspalum green color ratings (Table 11). Although it was not always significant, the green color ratings for trial run 1 were generally lower than trial run 2. During the 1st sequential rating, treatments 3, 6, and 7 (trial run 1) had the lowest seashore paspalum green color ratings. All other treatments had an acceptable level of seashore paspalum green color. The addition of metribuzin to treatment 3 (trial run 1 and 2) and treatment 6 (trial run 2) (i.e., treatments 5 and 7, respectfully) significantly increased seashore paspalum green color ratings. During the 2nd sequential rating, all treatments recovered to an acceptable green color level except treatments 3 and 6. Once again, the addition of metribuzin to treatments 3 and treatment 6 (i.e., treatments 5 and 7, respectfully) resulted in significantly higher seashore paspalum green color ratings for both trials. By the 3rd sequential rating, all treatments recovered to pre-spray green color conditions. During the 4th sequential rating (14DAS02), treatments 3 and 6 resulted in the lowest seashore paspalum green color ratings. The addition of metribuzin to treatment 3 and treatment 6 (i.e., treatments 5 and 7, respectfully) resulted in significantly higher seashore paspalum green color ratings for both trials. Trial run had an impact on treatments 3 and 6 green color ratings. Trial run 1 (winter season) green color was significantly lower than trial run 2 (summer season) for treatments 3 and 6 (Figure 8 and 9). All treatments recovered to an acceptable green color level by the 5th sequential rating.

Bermudagrass green color ratings

The results indicate a significant interaction between trial run and herbicide treatment effect ($P<0.05$) on bermudagrass green color ratings for the 1st, 4th, and 5th sequential ratings. There was no interaction for the 2nd sequential rating date and data was pooled over trial run (Table 12). Only the trial run was significant ($P<0.05$) for the 3rd sequential rating (see Table 12 caption). Although it was not always significant, the green color ratings for trial run 1 were generally lower than trial run 2. During the 1st sequential rating, treatments 2, 4, 5, and 7 (trial run 1resulted in the lowest level of bermudagrass green color. Treatments 1, 2, 3, and 6(trial run 2caused the least amount of green color loss in bermudagrass. The addition of metribuzin to treatments 1, 3 and 6 (i.e., treatments 4, 5, and 7, respectfully) significantly decreased bermudagrass green color ratings. During the 2nd sequential rating, all treatments were significantly lower than the untreated. Treatments 2, 4, 5, 6, and 7 had the lowest bermudagrass green color ratings. The addition of metribuzin to treatment 1 and 3 (i.e., treatments 4 and 5, respectfully) significantly lowered bermudagrass green color ratings. Trial run was the only significant factor on the 3rd sequential rating, data not presented. Overall, bermudagrass green color in trial run 1 was significantly lower than trial run 2. However, green color was restored to all treatments by the termination of the experiment. During the 4th sequential rating (14DAS02), bermudagrass green color ratings were lowest in treatments 4, 5, and 7. Although it was not significant, green color in trial run 1 were generally lower than trial run 2. The addition of metribuzin to treatments 1, 3, and 6 (i.e., treatments 4, 5, and 7, respectfully) resulted in significantly lower bermudagrass green color ratings. By the 5th sequential rating all treatments recovered.

Experiment 3. Seashore paspalum, bermudagrass, and goosegrass response to tank mixes and split applications of ethofumesate, metribuzin, mesotrione, and topramezone at West Loch Golf Course.

<u>Seashore paspalum green color ratings</u>

The results indicate a significant interaction between trial run and herbicide treatment effect ($P<0.05$) on seashore paspalum green color ratings for the 1st, 6th, 7th, and 8th sequential ratings. There was no interaction for the 2nd, 3rd, and 4th sequential ratings and data was pooled over trial run (Table 13). The 5th rating date, in both trial runs, did not have a significant treatment effect, data not presented (see Table 13 caption). During the 1st sequential rating treatments that included ethofumesate (i.e., all but treatment 1, trial run 2) had considerably less seashore paspalum green color loss. By the 2nd sequential rating all treatments recovered to an acceptable level of turf green color. During the 3rd sequential rating (7 days after spray of b-treatments) only treatment 4 showed significant green color loss. However, all treatments recovered to an acceptable green color level by the 4th rating date. The accidental irrigation stoppage in trial run 1 was not imposed after the 2nd application of the a-treatments. However, treatment 1 still showed significantly less seashore paspalum green color in trial run 1 compared to trial run 2 for the 6th, 7th, and 8th sequential ratings. With normal greens irrigation, seashore paspalum green color was only slightly reduced with the 2nd application of treatments 2, 3, and 4 (6^{th}, 7^{th}, 8^{th} sequential ratings). The second application of treatment 4b did not cause as much seashore paspalum green color loss as the initial application.

Bermudagrass green color ratings

The results indicate a significant interaction between trial run and herbicide treatment effect ($P<0.05$) on bermudagrass green color ratings for the 2^{nd}, 3^{rd}, 6^{th}, 7^{th}, and 8^{th} sequential ratings. There was no interaction for the 1^{st} sequential rating date and data was pooled over trial run (Table 14). The 4^{th} and 5^{th} rating dates, in both trial runs, did not have a significant treatment effect, data not presented (see Table 14 caption). All treatments except treatment 4 recorded a significant reduction in bermudagrass green color in the 1^{st} sequential rating. During the 2^{nd} sequential rating, an increased loss in bermudagrass green color was magnified for all treatments in trial run 1, a result attributed to the temporary 16 day stoppage of irrigation after initial spray application in trial run 1. On the 3^{rd} rating date, in trial run 1, treatments containing ethofumesate had prolonged bermudagrass green color loss. However, in trial run 2, which received normal greens irrigation throughout the experiment, only treatment 4 (only treatment containing mesotrione) had significantly lower bermudagrass green color compared to the other treatments. Bermudagrass green color returned to pre-spray conditions by the 4^{th} and 5^{th} rating dates and there was no treatment effect, data not reported. Bermudagrass green color loss, in trial run 2, was greatly increased when normal irrigation persisted throughout the entire experiment. After the second application (Trial 1 = 37 days after initial herbicide application, Trial 2 = 44 days after initial herbicide application), treatments 2 and 3, in trial run 2, had significantly lower bermudagrass green color than all other treatments in the 6^{th} and 7^{th} rating dates. However, bermudagrass green color was fully restored by the 8^{th} rating date for all treatments except treatment 4, where the mesotrione component caused a significant loss in green color, a similar response to the 1^{st} application of treatment 4b.

Goosegrass green color ratings

The results indicate a significant interaction between trial run and herbicide treatment effect ($P<0.05$) on goosegrass green color ratings for the 1^{st}, 2^{nd}, and 3^{rd} sequential ratings and on goosegrass control for the 5^{th}, 7^{th}, and 8^{th} sequential ratings. There was no interaction for the 4^{th} and 6^{th} sequential rating dates and data was pooled over trial run (Table 15). On the 1^{st} rating date, treatments 1, 2, and 3 had an increased goosegrass green color loss in trial run 1 compared to trial run 2. Trial run 1 had a 16 day stoppage in irrigation after the initial herbicide application. Treatments 1, 2, and 3 caused significant and similar goosegrass green color loss in the 2^{nd} and 3^{rd} rating dates. Although it was not significant, trial run 1 had numerically lower goosegrass green color ratings than trial run 2 (Figure 10 and 11). Treatment 4 caused minimal goosegrass green color loss for all rating dates. On the 4th and 6th rating dates, all treatments that included topramezone + metribuzin had significant goosegrass control. However, during the 5th, 7th, and 8th sequential rating, treatments 1, 2, 3 in trial run 1 had significantly higher goosegrass control compared to treatments in trial run 2. Overall, treatments containing topramezone + metribuzin had more consistent goosegrass control in trial run 1 compared to trial run 2. Treatment 4 did not provide goosegrass control during this study.

Goosegrass counts

The results indicate that there was not a significant interaction between trial run and herbicide treatment effect on goosegrass counts, data pooled over trial run (Table 16). Goosegrass counts were made after the completion of postemergence herbicide application. Treatments that contained topramezone + metribuzin were highly effective at reducing goosegrass counts. Treatment 4 was not effective in reducing goosegrass counts.

Experiment 4. Seashore paspalum response to mesotrione, and topramezone alone and in tank mix with ethofumesate and metribuzin at Hoakalei Country Club.

The results indicate a significant herbicide treatment effect ($P<0.05$) on seashore paspalum green color ratings (Table 17). At 7DAS01, treatment 5 (topramezone) had significantly lower seashore paspalum green color ratings compared to all other treatments. The addition of metribuzin and/or ethofumesate to topramezone resulted in significantly higher seashore paspalum green color. Visually similar results occurred with the addition of metribuzin and/or ethofumesate to mesotrione, but the green color ratings were not significantly different (Figure 12). At 14DAS01, a further reduction in seashore paspalum green color was recorded for treatment 5. The addition of metribuzin and/or ethofumesate to topramezone resulted in significantly higher seashore paspalum green color (Figure 13). All treatments recovered except for treatment 3 and 7, which had a slight reduction in seashore paspalum green color rating. At 21DAS01, all treatments returned to pre-spray green color level except treatment 7, which still showed a persistent green color reduction.

Experiment 5. Container grown seashore paspalum and bermudagrass response to ethofumesate, metribuzin, mesotrione, and topramezone alone and in tank mixes at Magoon Research Station.

Green color ratings

The results indicate a significant interaction between trial run, species, and herbicide treatment effect ($P<0.05$) on green color ratings for the 1st, 2nd, and 3rd sequential ratings in both grass species (Table 18). On the 1st sequential rating date, treatments 1 and 2 caused significant seashore paspalum green color loss in trial run 2 compared to trial run 1. The detrimental response of the seashore paspalum green color to treatments 1 and 2 was diminished by the irrigation application that occurred one hour after treatments were applied in trial run 1. Trial run 2 was set to a one-day rain delay (i.e., overhead irrigation turned off for one day) following herbicide application. On the first evaluation date after the application of herbicide treatments, metribuzin or ethofumesate added to mesotrione (treatments 2 and 3, respectfully) slightly increased the seashore paspalum green color in trial run 2. The addition of ethofumesate to mesotrione (treatments 3 and 4) greatly increased the loss of bermudagrass green color for both trials. Topramezone (treatment 5) resulted in a similar loss of green color for seashore paspalum and bermudagrass for both trials. Early irrigation did not diminish the detrimental effects of topramezone to seashore paspalum green color as recorded with mesotrione. Metribuzin reduced topramezone color loss in seashore paspalum and bermudagrass. The addition of ethofumesate to topramezone (treatment 7) slightly increased seashore paspalum green color, but had little effect on bermudagrass green color loss. The addition of metribuzin and ethofumesate to topramezone (treatment 8) was effective at increasing green color ratings for seashore paspalum, but not bermudagrass. Metribuzin alone (treatment 9) appeared to be more injurious to seashore paspalum compared to bermudagrass, but was not significant in the green color ratings. Metribuzin caused seashore paspalum's small needle shaped foliage to become clearly necrotic compared to only a slight color loss in bermudagrass with no foliar necrosis.

On the 2nd sequential rating date, seashore paspalum and bermudagrass green color recovered in treatments 1, 2, and 3 relative to the 1st sequential rating. Treatments 1 and 3 still showed some seashore paspalum green color loss in trial run 2. Treatment 4 reduced green color to a higher degree in bermudagrass than seashore paspalum. However, both species showed significant green color loss. Metribuzin and ethofumesate were effective at reducing seashore paspalum green color loss attributed to topramezone (treatments 6, 7, and 8). Bermudagrass recovered from the topramezone induced color loss, thus safening with metribuzin was not recorded. Bermudagrass recovery of green color, due to topramezone, was slower when ethofumesate was added (treatments 7 and 8). Seashore paspalum green color was significantly higher than bermudagrass for treatment 8. Treatment 9 consistently demonstrated that seashore paspalum is slightly less tolerant to metribuzin compared to bermudagrass (Figure 14).

On the 3rd sequential rating date, seashore paspalum and bermudagrass green color was restored in all treatments except for treatment 4 in trial run 2. Additionally, slight seashore paspalum green color loss persisted in treatment 5 during trial run 2. All treatments and species recovered to pre-spray green color by the 4th rating date (data not shown in Table 18).

Dry weights of clippings

The results indicate that there was an interaction between trial and species, treatment and species, and treatment and trial ($P<0.05$) on bermudagrass and seashore paspalum clipping dry weights 21 days after herbicide application (Table 19). The appendix provides the ANOVA table used to determine species, treatment and trial effects and their interactions. There was no three-way species x treatment x trial interaction recorded for 21-day clippings. The trial by species interaction means indicate that, bermudagrass had significantly higher clipping dry weights (in both trials) compared to seashore paspalum (means presented in Table 19 caption). When pooling the clippings weights over species (trial x treatment interaction), treatment 4, 7, and 8 (in both trials) recorded the lowest clipping dry weights. Treatments 4 and 7 (in both trials) recorded the highest reduction in clipping dry weights that were significantly lower compared to the untreated plants. When pooling the clipping weights over trial run (species x treatment interaction) treatments 4, 5, and 7 recorded seashore paspalum clipping dry weights that were significantly lower than the untreated. In the bermudagrass column, treatments 3, 4, 7, and 8 recorded significantly lower clipping dry weights compared to the untreated plants. Overall, the greatest reduction in clipping dry weights, for both species, was recorded with treatment 4. Although it was not significant, metribuzin numerically increased clipping dry weights when added to mesotrione or topramezone.

The means of clipping dry weights 21DAS01 (Table 19) were used for an alternative presentation of the treatment x species interaction means relative to untreated plants, see Figure 15. The percent reduction relative to untreated was derived using the equation ((untreated dry weight – treatment dry weight)/untreated dry weight)) x 100. Data not subjected to ANOVA and only provided for ease of comparisons for species response to treatments. Treatments 7 and 8 caused a greater reduction relative to the untreated dry weight for Bermudagrass compared to seashore paspalum (Figure 15).

The analysis of clippings collected 42 days after spray application did not indicate any significant experimental factors (i.e., trial, treatment, and species), data not presented. The 42-day clipping data indicates that long lasting growth impact on both species was not recorded with this experiment.

Shoot and root dry weights

Results indicate that only the herbicide treatment effect was significant for shoot dry weights. There were no 2 or 3-way treatment interactions (i.e., Species x Treatment x Trial, Species x Treatment, Species x Trial and Trial x Treatment). Table 20 provides treatment means with data pooled over species and trial runs. Treatments 4, 7, and 8 recorded significantly lower shoot dry weights compared to the untreated. Treatment 8 was significantly lower than treatment 1. The analysis of root dry weight did not indicate and 2 or 3-way significant interactions, the only significant factor was trial run ($P = 0.0136$, $F = 7.41$). Trial run 1 produced significantly higher root dry weights (4.32 g) than trial run 2 (1.55 g). Trial 1 had 134 days of growth prior to herbicide application and trial 2 had 92 days of growth prior to herbicide application. In addition, shorter day light duration and cooler overall temperatures occurred as the experiments were initiated sequentially with run 1 starting in summer months and trial 2 starting later in the calendar year.

Experiment 6. Seashore paspalum, bermudagrass, and goosegrass response to sequential tank mixes of ethofumesate, metribuzin, mesotrione, and topramezone followed by multiple applications of oxadiazon alone and in prepackaged mixture with bensulide at West Loch Golf Course.

<u>Seashore paspalum green color ratings</u>

The results indicate a significant postemergence herbicide treatment effect ($P<0.05$) on seashore paspalum green color ratings (Table 21) for the ratings taken prior to the application of preemergence herbicides (i.e., ratings recorded 7DAS01, 14DAS01, and 7DAS02). Data recorded after the application of preemergence herbicides (7DAP01 and 7DAP02) indicated that there was no interaction between postemergence and preemergence herbicide effects, data pooled over preemergence herbicide. At 7DAS01, post 3 and 4 had significantly lower seashore paspalum green color ratings. All other treatments had reduced, but commercially acceptable levels of turf color. At 14DAS01, all treatments recovered to an acceptable level of green color. Post 3 and 4 continued to show the highest level of green color loss. At 7DAS02 and 14DAS02 (7DAP01), post 1 and 5 had the highest level of seashore paspalum green color. All other treatments showed significant green color loss. Post 4 had the lowest seashore paspalum green color ratings 21DAS02 (7DAP02). Seashore paspalum green color ratings recovered in all other treatments.

<u>Bermudagrass green color ratings</u>

The results indicate a significant postemergence herbicide treatment effect ($P<0.05$) on bermudagrass green color ratings (Table 22) for the ratings taken prior to the application of preemergence herbicides (i.e., ratings recorded 7DAS01, 14DAS01, and 7DAS02). Data recorded after the application of preemergence herbicides (7DAP01 and 7DAP02) indicated that there was no interaction between postemergence and preemergence herbicide effects, data pooled over preemergence herbicide. Post 1, 2, 3, and 4 significantly decreased bermudagrass green color 7DAS01 and 14DAS01. At 7DAS02, post 5 caused significant bermudagrass green color loss compared to the untreated. However, post 1, 2, 3, and 4 continued to have significantly lower bermudagrass green color compared to post 5. All treatments besides post 6 resulted in significantly lower bermudagrass green color ratings 14DAS02 (7DAP01). At 21DAS02 (7DAP02), post 5 bermudagrass green color slightly recovered. Post 1, 2, 3, 4 continued to show significant bermudagrass green color loss.

Goosegrass green color ratings

The results indicate a significant postemergence herbicide treatment effect ($P<0.05$) on goosegrass green color ratings (Table 23) for the ratings taken prior to the application of preemergence herbicides (i.e., ratings recorded 7DAS01, 14DAS01, and 7DAS02). There was a significant interaction ($P<0.05$) between postemergence herbicide treatment effect and preemergence herbicide treatment effect on goosegrass green color ratings only on 08/08/17 (14DAS02, 7DAP01) (Table 23). There was no interaction for all other rating dates, data pooled over preemergence herbicide treatment for the final rating date of 08/15/17. At 7DAS01, post 3 and 4 had significantly lower goosegrass green color ratings compared to all other treatments. Post 1 and 2 had a slight, but significant reduction in goosegrass green color compared to the untreated. However, goosegrass in post 1 and 2 recovered 14DAS01. At 14DAS01, post 3 and 4 continued to record a decrease goosegrass green color. All herbicide treatments had significant goosegrass green color loss 7DAS02 and 14DAS02 (7DAP01) in contrast to the untreated plots. The sprayable formulation of oxadiazon (Ronstar® Flo) caused significantly lower goosegrass green color compared to the other preemergence treatments (premixed granular formulation) and the untreated plots 14DAS02 (7DAP01). At 21DAS02 (7DAP02), post 5 and 6 had an increase in goosegrass green color. All other treatments recorded no goosegrass green color representing completed death of foliar tissues.

Seashore paspalum percent cover

The results indicated a significant interaction ($P<0.05$) between postemergence and preemergence herbicide treatment factors on percent of seashore paspalum turf canopy (Table 24). At 34DAS02 (20DAP02), post 3 + Ronstar® Flo, post 4 + Anderson's Goosegrass/Crabgrass and post 4 + Ronstar® Flo had significantly less seashore paspalum turf canopy than untreated plots (post 6). Post 4 with no preemergence herbicide application was not significantly different than untreated plots, indicating that when treatments cause seashore paspalum canopy loss, preemergence herbicide application stunts seashore paspalum turf growth needed to fill in bare ground areas. The rest of the treatments were not significantly different compared to untreated plots. Post 1, 5, and 6 had the highest percentage of seashore paspalum canopy cover. At 50DAS02 (36DAP02), only post 3 (Ronstar® Flo) and post 4 (Anderson's Goosegrass/Crabgrass and Ronstar® Flo) had a slight decrease in seashore paspalum canopy cover.

Goosegrass percent change in counts

The results indicate a significant postemergence herbicide treatment effect ($P<0.05$) on percent change of goosegrass counts (Table 25). There was no interaction between postemergence and preemergence herbicide effects, data pooled over preemergence herbicide. Post 1, 2, 3, and 4 had a significant reduction in goosegrass compared to the untreated. Post 5 had a slight reduction, but was not as effective compared to the other treatments.

Discussion

Experiment 1. Seashore paspalum and goosegrass response to mesotrione, metribuzin, and topramezone single product and tank mixes at Pali Golf Course.

Overall, the study revealed differences between postemergence herbicides applied alone and in combination in terms of goosegrass and seashore paspalum green color loss. Topramezone and mesotrione alone did not provide goosegrass control at the rates of application used in this greens study. This was different from what Cox et al. (2017) found, in which they achieved goosegrass control with topramezone alone (application rates were 0.006 kg/ha and 0.012 kg/ha). Mesotrione + metribuzin tank mix also lacked goosegrass control. Topramezone caused more seashore paspalum turf injury compared to mesotrione. The results were consistent with Cox et al. (2017), which found that topramezone alone in bermudagrass caused significant turf discoloration. Topramezone + metribuzin tank mix effectively controlled goosegrass and the 3-way tank mix (topramezone + mesotrione + metribuzin) did not provide additional goose grass control. Single applications of herbicide treatments did not provide goosegrass control, two applications were needed for effective goosegrass control. However, seashore paspalum injury was severe. Increased seashore paspalum injury, at this location, was attributed to a poorly drained practice green due to motorized mower compaction (personal observation). Several times during the course of the experiment, the practice green was soggy and mowing under these wet conditions resulted in scalping of the turf most severely affected by herbicide treatments. A temporary increase in mowing height, prior to herbicide application, should be considered when attempting to employ these herbicides and their combination on a poorly drained green. An important finding in this study was seashore paspalum turf bleaching attributed to topramezone and mesotrione was reduced with the addition of metribuzin. Boyd et al. (2016b) found that the addition of chelated iron to a tank mix acts as a safener to bermudagrass green color loss. However, the addition of a photosystem II inhibitor, such as metribuzin, to a tank mixture with an HPPD inhibitor herbicide was reported to increase phototoxicity due complementary mode of actions or synergism (Armel et al. 2005). Metribuzin can result in stunted plant growth (Gunsolus and Curran 2002) and reduces seashore paspalum growth when applied at low concentrations (DeFrank, personal communication 2018). Mesotrione and topramezone bleaching occurs at the growing points of the plants and is only seen in the new growth (Anonymous 2017d; Anonymous 2017b). Metribuzin safening of seashore paspalum green color loss, caused by mesotrione and topramezone applications, could be attributed to stunted seashore paspalum growth resulting in less the new growth and subsequent reduced expression of foliar bleaching.

Experiment 2. Seashore paspalum and bermudagrass response to ethofumesate in combination with metribuzin, mesotrione, and topramezone at Hoakalei Country Club.

The addition of ethofumesate reduced topramezone and mesotrione bleaching of seashore paspalum turf. Mesotrione and topramezone bleaching occurs at the growing points of the plants and is only seen in the new growth (Anonymous 2017d; Anonymous 2017b). The mode of action of ethofumesate is unknown. However, ethofumesate is reported to stunt plant growth (Anonymous 2017a). Thus, the safening effect of ethofumesate to topramezone and mesotrione induced seashore paspalum bleaching could be due ethofumesate growth inhibition that reduces new foliar growth and the expression of bleached foliage. The addition of metribuzin to the ethofumesate tank mixes enhanced the seashore paspalum safening (i.e., more green color), a response similar to that observed at the Pali Golf Course, but to a higher degree at Hoakalei. The added safening could be due to a cumulative effect of the ethofumesate and metribuzin tank mix, a combination that would further reduce the bleaching caused by mesotrione or topramezone. The additional safening could also be attributed to the different cultivars used (Pali = 'Salam', Hoakalei = 'SeaDwarf'), different soil types (Pali = Kaneohe silty clay, Hoakalei = imported soil over a coral outcrop) or the different environmental conditions (Pali = windward side of Oahu (increased cloud cover and higher rainfall levels), Hoakalei = leeward side of Oahu (higher level of solar input and lower levels of rainfall)).

The addition of metribuzin to the ethofumesate tank mixes increased bermudagrass injury. Treatments that included metribuzin also showed more activity against bermudagrass in the winter compared to summer applications. Winter applications may have been enhanced due to slower bermudagrass growth. Bermudagrass has slower growth in the winter compared to seashore paspalum (Foy 2006). Slower growing bermudagrass would could have reduced its ability to metabolize metribuzin, resulting in greater loss of green color. Winter applications may also have been enhanced due to less irrigation applied due to generally cooler conditions and less evaporative stress. Metribuzin, mesotrione, and topramezone are highly water-soluble and have moderate to very high leaching potentials (Lewis et al. 20016). With less irrigation, the chemicals would stay in the bermudagrass root zone longer allowing for more absorption. This increased root absorption could cause the more intense and persistent green color loss during the winter months. Conversely, the decreased discoloration in the summer could be attributed to healthy, faster growing turf that could more rapidly metabolize absorbed toxins, such as metribuzin.

Treatments 4 and 5 (mesotrione + metribuzin + ethofumesate and topramezone + metribuzin + ethofumesate, respectfully) were identified as the most effective treatments for bermudagrass suppression with good safety (i.e., minimal loss of green color) on seashore paspalum. However, long-term suppression was not achieved in this study with the course of treatments applied. Long-term selective suppression of bermudagrass will require multiple sequential applications, a use pattern described on the current ethofumesate product label (Anonymous 2017a). Although persistent bermudagrass suppression was not obtained, treatments 4 and 5 could be used for other grassy weed control in seashore paspalum turf.

Experiment 3. Seashore paspalum, bermudagrass, and goosegrass response to tank mixes and split applications of ethofumesate, metribuzin, mesotrione, and topramezone at West Loch Golf Course.

All treatments caused minimal seashore paspalum green color loss and the stoppage in irrigation had little impact on green color ratings in untreated portions of the green. The addition of metribuzin to topramezone was effective at reducing seashore paspalum bleaching with minimal loss of green color and turf canopy. At the Pali Golf Course, metribuzin reduced the bleaching associated with topramezone, but caused significant turf injury (loss of green color and necrotic foliar tissues) and canopy loss. Since the Pali and West Loch courses both use the same turf cultivar ('Salam'), the differences recorded with in turf green color loss could be due different soil types (Pali = Kaneohe silty clay, West Loch = Helemano silty clay and Keaau clay, saline) or the different environmental conditions (Pali = windward side of Oahu (increased cloud cover and higher rainfall levels), West Loch = leeward side of Oahu (higher level of solar input and lower levels of rainfall)). The addition of ethofumesate only slightly enhanced safening to topramezone bleaching, a result consistent at both West Loch ('Salam') and Hoakalei ('SeaDwarf') golf courses

Maximum bermudagrass injury occurred in treatments that had ethofumesate and/or mesotrione. The increased loss in bermudagrass green color was magnified in all treatments due to the temporary stoppage of irrigation during trial run 1. The enhanced reduction in bermudagrass green color, due to irrigation stoppage, persisted longer in treatments containing ethofumesate. The enhanced bermudagrass loss of green color in trial run 1 was greatly increased compared to trial run

2 where irrigation persisted throughout the entire experiment. The post spray dry down provided increased bermudagrass turf injury comparted to the same treatments where regular irrigation was used during the course of the second trial. Trial run did not have a significant effect on seashore paspalum green color loss. Initially, the difference seen between turf species and their response to the imposed dry down was attributed to differences in drought tolerance. According to Duncan and Carrow (2000), seashore paspalum has better drought tolerance than bermudagrass. Thus, the added drought stress was initially thought to be the cause of the increased bermudagrass injury following the post-spray dry down. However, another factor contributing to increased herbicide impact, which is supported by chemical properties of the herbicides used here (see Chapter 1, Table 2), is prolonged residency of chemicals in the root zone due to reduced leaching. Lewis et al. (2016) report that metribuzin, mesotrione, and topramezone are highly water-soluble and have moderate to very high leaching potentials. With the cessation of irrigation following herbicide application in trial 1, longer persistence in the bermudagrass root zone allowed for more absorption, leading to increased bermudagrass injury.

The only treatment that did not provide goosegrass control was the split application of ethofumesate followed by mesotrione + metribuzin + ethofumesate. Treatments that included topramezone + metribuzin in tank mix were highly effective at controlling goosegrass and reducing goosegrass counts at the end of the evaluation period, a similar response recorded at the Pali Golf Course. However, only a single application, followed by a post-spray dry down, was needed for complete goosegrass control in trial 1 compared to two applications required for comparable goosegrass control with regular irrigation in trial 2. The enhance herbicide effectiveness following the post-spray dry down can be attributed to drought stress imposed on the goosegrass and/or longer residency of active herbicide levels in the turf root zone. Treatments 1, 2, and 3 were highly effective at controlling mature goosegrass. However, goosegrass seedlings quickly emerged in the open turf spaces remaining after mature goosegrass eradication. Timely application of preemergence herbicide is essential to a comprehensive goosegrass control strategy that includes elimination of existing goosegrass and their quick to emerge seedlings.

Experiment 4. Seashore paspalum response to mesotrione, and topramezone alone and in tank mix with ethofumesate and metribuzin at Hoakalei Country Club.

Seashore paspalum turf bleaching was reduced with the addition of metribuzin and/or ethofumesate to the tank mix. The addition of ethofumesate alone provided some seashore paspalum safening (i.e., more green color), but to a lesser degree than metribuzin. All tank mixes that included metribuzin recovered to pre-spray conditions by 14DAS01, 7 days quicker than treatments with topramezone or mesotrione alone. Tank mixes with ethofumesate alone still showed slight discoloration 21DAS01. The safening effect of metribuzin and ethofumesate is consistent with the previous Hoakalei and West Loch trials. Clearly, the addition of metribuzin and/or ethofumesate helps safen seashore paspalum to mesotrione and topramezone bleaching. However, it is unclear if treatments are maintaining seashore paspalum green color due to blockage of metabolic pathways or due to growth suppression. A container study (Experiment 5) was initiated to further characterize the response of both Bermuda grass and seashore paspalum to herbicides applied alone and in tank mixtures.

Experiment 5. Container grown seashore paspalum and bermudagrass response to ethofumesate, metribuzin, mesotrione, and topramezone alone and in tank mixes at Magoon Research Station.

Mesotrione and topramezone applied alone caused more green color loss discoloration (Table 18 and Figure 14) and growth suppression (Table 19) in seashore paspalum relative to bermudagrass. Turf clippings collected 21 DAS01 indicated that the addition of metribuzin and/or ethofumesate to mesotrione or topramezone did not prevent growth suppression (Figure 15). Seashore paspalum growth slightly increased with the addition of metribuzin to mesotrione or topramezone relative to mesotrione or topramezone applied alone. Ethofumesate decreased seashore paspalum growth when added to mesotrione, but when added to topramezone it slightly increased growth relative to topramezone alone. The reduced turf green color loss associated with metribuzin as a tank mix component in field studies was not as obvious in the container study. Decreased green color loss attributed to metribuzin could be due to cultivar differences (‘Salam” & ‘Sea Dwarf’ in the field vs. ‘SeaStar’ in containers) or due to a dramatically different root zone environment between field and container grown plants. Plants grown in containers tend to be more sensitive to herbicides because they generally have smaller root systems than filed grown established plants (Wilen and Elmore 2014). The addition of metribuzin alone to mesotrione or topramezone did not have an impact on bermudagrass green color or growth. However, treatments with ethofumesate resulted in significantly lower green color ratings and growth. This is consistent with the results found at Hoakalei Country Club and West Loch golf course. It is also consistent with the ethofumesate label, which describes selective bermudagrass suppression (Anonymous 2017a).

Treatments 4, 7, and 8 provided the greatest differences in green color ratings that were higher for seashore paspalum (Table 18 and Figure 14). Treatment 4 recorded the highest but level of growth reduction for both the seashore paspalum and bermudagrass (Table 19) even though seashore paspalum green color was much higher than bermudagrass. Treatments 7 and 8 caused a greater reduction relative to the untreated dry weight for bermudagrass compared to seashore paspalum (Figure 15). Thus, treatments 7 and 8 provided the best selective bermudagrass suppression in this study.

Experiment 6. Seashore paspalum, bermudagrass, and goosegrass response to sequential tank mixes of ethofumesate, metribuzin, mesotrione, and topramezone followed by multiple applications of oxadiazon alone and in prepackaged mixture with bensulide at West Loch Golf Course.

The sequence of postemergence herbicide tank mix application had a significant impact on seashore paspalum maximum green color and the loss of seashore paspalum canopy. The clearest representation of this result is seen by comparing turf cover in post 1 and post 3 (Figure 16). Post 1 included the treatment of mesotrione + metribuzin + ethofumesate followed by the treatment of topramezone + metribuzin + ethofumesate. Post 3 had the same total amount of chemicals applied as post 1, but had the tank mix containing topramezone applied first. The sequence of the herbicides applied in post 1 had the highest seashore paspalum green color ratings and resulted in the least amount of seashore paspalum canopy loss. Preemergence herbicide formulation (granular vs liquid) had an impact on seashore paspalum turf recovery (Figure 17). Preemergence herbicide can be safely applied to seashore paspalum greens if there is no significant turf canopy loss due to postemergence applications. Once turf canopy is lost, the application of preemergence herbicides, regardless of form, severely delayed turf recovery. Both post 1 and 3 treatments had similar impact on bermudagrass injury and time required for green color restoration and provided excellent goosegrass control. Therefore, since post 1 was the safest treatment on seashore paspalum while causing similar damage to the bermudagrass and goosegrass as the other treatments, post 1 would be best for bermudagrass suppression and established goosegrass kill in a seashore paspalum green. Bermudagrass suppression could be enhanced with a timely preemergence herbicide (i.e., 1-3 days after last post) to prevent bermudagrass reestablishment. Multiple applications of post 1 followed by timely applications of preemergence herbicides should be considered for long-term bermudagrass suppression.

Treatments that caused seashore paspalum stand reduction or did not control living goosegrass (i.e., untreated) resulted in the highest level of goosegrass counts at the last evaluation event. Nishimoto and McCarty (1997) attributed the highest level of goosegrass seedling emergence on bare ground and in scalped and/or thin turf to the stimulating effects of light and maximum diurnal fluctuations in soil surface temperatures. Higher than expected goosegrass seedling counts, in this experiment, were due to a late preemergence application after seedlings emerged and not due to a product failure. These results highlight the need for timely preemergence applications prior to any goosegrass seedling emergence, especially when open spaces in turf canopy results from the elimination of existing goosegrass plants

A best management practice (BMP) is proposed incorporating bermudagrass suppression and goosegrass control during seashore paspalum greens renovation (Table 26). Incorporating the information in this thesis and the demonstrated impact of herbicide tank mix sequence on seashore turf canopy loss, the proposed BMP is initiated with application of post A to retain seashore paspalum green color and prevent turf canopy loss while imposing maximum bermudagrass suppression. However, this treatment does not provide any goosegrass control. At 14 days after initial application, post B should be applied incorporating a 3-5 day post-spray dry down period. Post B provides goosegrass control and additional bermudagrass suppression. The imposed dry down is necessary to provide goosegrass control with one spray application. Following the dry down, normal irrigation is applied to flush the chemicals from the root zone to aid in seashore paspalum turf recovery and to rehydrate the greens to allow solid soil core extraction with aeration equipment (Figure 18). Without adequate hydration, soil cores fall apart and prevent efficient collection and removal from the greens surface. After core aeration, top dressing, brushing in the sand, and fertilization (Figure 19), sequential applications of preemergence herbicides are essential to prevent goosegrass seedling emergence and bermudagrass reestablishment. Splitting the preemergence herbicide applications helps reduce turf green color loss by applying multiple low doses rather than a single full rate (Anonymous 2006). Incorporating weed control into a greens renovation allows turf managers to mask any herbicide injury as the anticipated turf injury caused by the renovation procedures. The proposed experimental procedures in this protocol can be cited to support justify product label changes for use in Hawaii. Suggested wording for a 24(c) or “Special Local Need Label” could include: “Do not apply to seashore paspalum turf less than 1.3 cm high unless injury or removal of turf can be tolerated.” This suggested label wording would provide Hawaii’s seashore paspalum turf managers with much need weed control chemicals tools as well as protect herbicide providers from claims of unacceptable turf injury.

Overall Conclusions and Future Directions

Goosegrass control in seashore paspalum can be achieved with a tank mix that includes topramezone + metribuzin. Furthermore, incorporating a post-spray dry down following the initial herbicide application results in effective goosegrass control with one herbicide spray application, a use pattern consistent with current label wording for topramezone (Anonymous 2017b). Follow up studies would be helpful to characterize the length of dry down needed for effective weed control and determine the impact of fresh vs non-potable irrigation on the post-spray dry down and turf recovery. Another root zone based consideration that could impact the effectiveness of the post-spray dry down would be greens site/construction that enhances drainage and allows for a high degree of control to remove herbicide from the root zone. Managers that have a high degree of confidence in their ability to control the persistence of herbicide in the greens root zone can maximize the effectiveness of herbicide applications and then minimize the recovery time of the affected turf. Another key finding in this study is the selective bermudagrass suppression with the tank mix of mesotrione + metribuzin + ethofumesate followed by the tank mix of topramezone + metribuzin + ethofumesate. Multiple sequences would be needed to maintain the selective bermudagrass suppression, but it is beyond the scope of this study to determine how many applications are required and the time of year in Hawaii for optimum bermudagrass suppression coupled with seashore paspalum greens safety. A synthesis of the results reported here served as the basis for a proposed seashore paspalum greens renovation Best Management Practice (BPM). The proposed BMP incorporates goose grass weed control as well as Bermuda grass suppression (Table 26). Insuring good greens drainage is essential to flushing the herbicides out of the root zone following the post-spray dry down. The results found in this thesis help provide support to label amendments to the herbicides described in this study and to allow their use in Hawaii. Additional studies should look at different seashore paspalum cultivars and different environmental conditions to determine if their impact on the results reported in this thesis.

Tables and Figures

Table 3. Experiment 1. Application rates and sequence of postemergence herbicide treatments evaluated on seashore paspalum (*Paspalum vaginatum* ‘Salam’) and goosegrass (*Eleusine indica*) at the Pali Golf Course. Days after 1st (##DAS01).

Herbicide Treatment + MSO (1.0% v/v)**	Application Rate (kg ai/ha)	Application Sequence	
		Day-0	14DAS01
1 Mesotrione	0.070	Apply Trt 1	Apply Trt 1
2 Mesotrione + Metribuzin	0.070 0.105	Apply Trt 2	Apply Trt 2
3 Topramezone	0.012	Apply Trt 3	Skip*
4 Topramezone + Metribuzin	0.012 0.105	Apply Trt 4	Apply Trt 4
5 Topramezone + Mesotrione + Metribuzin	0.012 0.070 0.105	Apply Trt 5	Apply Trt 5

* Second application not applied due to excessive turf injury.
** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 4. Experiment 2. Application rates and sequence of postemergence herbicide treatments evaluated on seashore paspalum (*Paspalum vaginatum* ‘SeaDwarf’) and bermudagrass (*Cynodon dactylon*) at the Hoakalei Golf Course. **Trial 1** (T1): application dates – 12/21/16 and 01/31/17. **Trial 2** (T2): application dates – 06/20/17 and 08/01/17. Days after 1st spray application (##DAS01).

Herbicide Treatment + MSO (2% v/v)*	Application Rate (kg ai/ha)	Application Sequence	
		1st Application	2nd Application T1-41DAS01 T2-42DAS01
1 Mesotrione + Ethofumesate	 0.070 1.121	Apply Trt 1	Apply Trt 1
2 Metribuzin + Ethofumesate	 0.210 1.121	Apply Trt 2	Apply Trt 2
3 Topramezone + Ethofumesate	 0.025 1.12	Apply Trt 3	Apply Trt 3
4 Mesotrione + Metribuzin + Ethofumesate	 0.070 0.210 1.121	Apply Trt 4	Apply Trt 4
5 Topramezone + Metribuzin + Ethofumesate	 0.025 0.210 1.121	Apply Trt 5	Apply Trt 5
6 Topramezone + Mesotrione + Ethofumesate	 0.025 0.070 1.121	Apply Trt 6	Apply Trt 6
7 Topramezone + Mesotrione + Metribuzin + Ethofumesate	 0.025 0.070 0.210 1.121	Apply Trt 7	Apply Trt 7
8 Untreated	-	-	-

* All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 5. Experiment 3. Application rates and sequence of postemergence herbicide treatments evaluated on seashore paspalum (*Paspalum vaginatum* 'Salam'), bermudagrass (*Cynodon dactylon*), and goosegrass (*Eleusine indica*) at the West Loch Golf Course. **Trial 1** (T1): application dates – 02/14/17, 02/28/17, 03/23/17 and 04/06/17. **Trial 2** (T2): application dates – 03/07/17, 03/21/17, 04/20/17and 05/04/17. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

Herbicide Treatment + MSO (1.0% v/v)*	Application Rate (kg ai/ha)	Application Sequence			
		1st Application	2nd Application T1-14DAS01a T2-14DAS01a	3rd Application T1-23DAS01b T2-30DAS01b	4th Application T1-14DAS02a T2-14DAS02a
1 a) Topramezone + Metribuzin	 0.012 0.105	Apply Trt 1a	Skip	Apply Trt 1a	Skip
2 a) Topramezone + Metribuzin + Ethofumesate b) Ethofumesate	 0.012 0.105 0.560 0.560	Apply Trt 2a	Apply Trt 2b	Apply Trt 2a	Apply Trt 2b
3 a) Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121	Apply Trt 3a	Skip	Apply Trt 3a	Skip
4 a) Ethofumesate b)Mesotrione + Metribuzin + Ethofumesate	 0.560 0.070 0.105 0.560	Apply Trt 4a	Apply Trt 4b	Apply Trt 4a	Apply Trt 4b

* All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 6. Experiment 4. Application date and rates of postemergence herbicide treatments evaluated on seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') at the Hoakalei Golf Course.

Herbicide Treatment + MSO (2.0% v/v)*	Application Rate (kg ai/ha)	Application Date
		08/01/17
1 Mesotrione	0.070	Apply Trt 1
2 Mesotrione + Metribuzin	0.070 0.210	Apply Trt 2
3 Mesotrione + Ethofumesate	0.070 1.121	Apply Trt 3
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.210 1.121	Apply Trt 4
5 Topramezone	0.025	Apply Trt 5
6 Topramezone + Metribuzin	0.025 0.210	Apply Trt 6
7 Topramezone + Ethofumesate	0.025 1.121	Apply Trt 7
8 Topramezone + Metribuzin + Ethofumesate	0.025 0.210 1.121	Apply Trt 8
9 Untreated	-	-

* All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 7. Experiment 5. Application date and rates of postemergence herbicides evaluated on seashore paspalum (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (*Cynodon dactylon*) turf growing in containers at the Magoon Research Station. Application dates – **Trial 1** = 09/29/17, **Trial 2** = 10/13/17.

Herbicide Treatment + MSO (1% v/v)*	Application Rate (kg ai/ha)	Application Date
		Day-0
1 Mesotrione	0.070	Apply Trt 1
2 Mesotrione + Metribuzin	0.070 0.105	Apply Trt 2
3 Mesotrione + Ethofumesate	0.070 1.121	Apply Trt 3
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.105 1.121	Apply Trt 4
5 Topramezone	0.012	Apply Trt 5
6 Topramezone + Metribuzin	0.012 0.105	Apply Trt 6
7 Topramezone + Ethofumesate	0.012 1.121	Apply Trt 7
8 Topramezone + Metribuzin + Ethofumesate	0.012 0.105 1.121	Apply Trt 8
9 Metribuzin	0.105	Apply Trt 9
10 Untreated	-	-

* All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 8. Experiment 6. Application dates and rates of postemergence and preemergence herbicide treatments evaluated on seashore paspalum (*Paspalum vaginatum* 'Salam'), bermudagrass (*Cynodon dactylon*), and goosegrass (*Eleusine indica*) at the West Loch Golf Course. Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1.0% v/v)*	Application Rate (kg ai/ha)	Preemergence Herbicide (0.841 kg oxadiazon/ha)	Application Dates			
			07/11/17	07/25/17	08/01/17	08/08/17
			Day 0	14DAS01	7DAS02	7DAP01
POST 1 a) Mesotrione + Metribuzin + Ethofumesate + b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	Apply POST 1a	Apply POST 1b	Apply Preemergence Herbicides	Apply Preemergence Herbicides
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	Apply POST 2a	Apply POST 2b	Apply Preemergence Herbicides	Apply Preemergence Herbicides
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	Apply POST 3a	Apply Post 3b	Apply Preemergence Herbicides	Apply Preemergence Herbicides
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	Apply POST 4a	Apply POST 4b	Apply Preemergence Herbicides	Apply Preemergence Herbicides
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	Skip	Apply POST 5b	Apply Preemergence Herbicides	Apply Preemergence Herbicides
POST 6 Untreated	-	Untreated Anderson's Goosegrass/ Crabgrass Ronstar® Flo	-	-	Apply Preemergence Herbicides	Apply Preemergence Herbicides

* All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 9. Experiment 1. Response of seashore paspalum (*Paspalum vaginatum* 'Salam') greens to postemergence herbicides applied at the Pali Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application dates – 04/16/16 and 04/20/16. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

<table>
<tr><th rowspan="2">Herbicide Treatment +
MSO (1.0% v/v)***</th><th rowspan="2">Application Rate
(kg ai/ha)</th><th colspan="6">Dates for Visual Green Color Ratings (%)*</th></tr>
<tr><th>04/13/16
7 DAS01</th><th>04/19/16
13DAS01</th><th></th><th>04/27/16
7DAS02</th><th>05/4/16
14DAS02</th><th>05/11/16
21DAS02</th></tr>
<tr><td>1
Mesotrione</td><td>0.070</td><td>64.5 B</td><td>84.5 B</td><td rowspan="7">Second herbicide application applied 04/20/16 for all treatments except #3.</td><td>45.5 C</td><td>90.5 A</td><td>93.8 A</td></tr>
<tr><td>2
Mesotrione +
Metribuzin</td><td>0.070
0.105</td><td>80.8 A</td><td>92.0 A</td><td>65.0 B</td><td>90.3 A</td><td>92.8 AB</td></tr>
<tr><td>3
Topramezone</td><td>0.012</td><td>44.0 C</td><td>24.5 D</td><td>85.3 A</td><td>95.5 A</td><td>95.3 A</td></tr>
<tr><td>4
Topramezone +
Metribuzin</td><td>0.012
0.105</td><td>68.3 B</td><td>75.8 C</td><td>11.3 E</td><td>67.5 B</td><td>89.5 C</td></tr>
<tr><td>5
Topramezone +
Mesotrione +
Metribuzin</td><td>0.012
0.070
0.105</td><td>66.3 B</td><td>80.5 B</td><td>29.0 D</td><td>71.3 B</td><td>90.3 BC</td></tr>
<tr><td colspan="2">F value</td><td>87.73</td><td>712.45</td><td>1102.82</td><td>84.93</td><td>12.46</td></tr>
<tr><td colspan="2">P value</td><td>< 0.0001</td><td>< 0.0001</td><td>< 0.0001</td><td>< 0.0001</td><td>0.0003</td></tr>
</table>

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at $P<0.05$.

** Second application not applied due to excessive turf injury.

*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 10. Experiment 1. Response of goosegrass (*Eleusine indica*) in greens to postemergence herbicides applied at the Pali Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application dates – 04/16/16 and 04/20/16. Days after 1st and 2nd spray application expressed as (##DAS01, ## DAS02, respectively).

Herbicide Treatment + MSO (1.0% v/v)***	Application Rate (kg ai/ha)	Dates for Visual Green Color Ratings (%)*					
		04/13/16 7 DAS01	04/19/16 13DAS01		04/27/16 7DAS02	05/4/16 14DAS02	05/11/16 21DAS02
1 Mesotrione	0.070	17.8 B	87.8 A	Second herbicide application applied 04/20/16 for all treatments except #3.	64.0 A	88.8 A	96.0 A
2 Mesotrione + Metribuzin	0.070 0.105	77.3 A	88.3 A		16.3 C	80.0 A	96.0 A
3 Topramezone	0.012	16.3 B	24.8 BC		48.3 B	84.0 A	94.5 A
4 Topramezone + Metribuzin	0.012 0.105	75.0 A	14.3 C		0.0 D	0.0 B	0.0 B
5 Topramezone + Mesotrione + Metribuzin	0.012 0.070 0.105	78.3 A	37.8 B		0.0 D	0.0 B	0.0 B
F value		466	104.85		426.32	185.8	6081
P value		< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** Second application not applied due to excessive turf injury.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 11. Experiment 2. Response of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') fairways to postemergence herbicides applied at the Hoakalei Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). **Trial 1**: application dates – 12/21/16 and 01/31/17, rating dates – 12/30/16, 01/11/17, 01/31/17, 02/14/17, and 03/07/17. **Trial 2**: application dates – 06/20/17 and 08/01/17, rating dates – 06/27/17, 07/11/17, 07/25/17, 08/15/17, and 08/23/17. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

Herbicide Treatment + MSO (2.0% v/v)**	Application Rate (kg ai/ha)	Trial	Green Color (%)*				
			1st Rating	2nd Rating	3rd Rating	4th Rating	5th Rating
		1	9DAS01	21DAS01	41DAS01	14DAS02	35DAS02
		2	7DAS01	21DAS01	35DAS01	14DAS02	22DAS02
1 Mesotrione + Ethofumesate	0.070 1.121	1	83.8 DEF	81.5 ABC	97.3 AB	92.5 ABC	98.0 A
		2	91.5 ABCD	96.3 A	97.8 A	89.5 CD	94.0 CDE
2 Metribuzin + Ethofumesate	0.210 1.121	1	95.8 ABC	93.5 A	96.5 AB	97.3 A	97.8 AB
		2	95.8 ABC	97.5 A	98.0 A	94.8 ABC	96.3 ABC
3 Topramezone + Ethofumesate	0.025 1.121	1	77.5 EFG	72.5 BCD	98.0 A	62.3 F	98.5 A
		2	76.3 FG	45.5 E	97.5 AB	83 E	91.5 E
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.210 1.121	1	82.5 DEF	94.3 A	98.0 A	97.5 A	98.0 A
		2	91.3 ABCD	97.3 A	97.8 A	95.5 AB	96.0 ABC
5 Topramezone + Metribuzin + Ethofumesate	0.025 0.210 1.121	1	89.8 BCD	95.8 A	97.8 A	90.8 BC	97.5 AB
		2	86.0 DE	97.0 A	98.0 A	95.0 ABC	96.0 ABC
6 Topramezone + Mesotrione + Ethofumesate	0.025 0.070 1.121	1	66.3 HI	65 CDE	95.5 B	59.5 F	98.0 A
		2	71.5 GH	55 DE	97.3 AB	84.5 DE	93.0 DE
7 Topramezone + Mesotrione + Metribuzin + Ethofumesate	0.025 0.070 0.210 1.121	1	61.3 I	86 AB	98.0 A	80.3 E	98.5 A
		2	88.25 CD	97.3 A	97.5 AB	94.5 ABC	96.3 ABC
8 Untreated	-	1	99.8 A	97.3 A	97.8 A	98.0 A	98.0 A
		2	98.3 AB	98.5 A	97.8 A	96.0 AB	95.0 BCD
F value			17.1	5.32	2.76	53.21	7.18
P value			< 0.0001	0.0002	0.0187	< 0.0001	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at $P<0.05$.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 12. Experiment 2. Response of bermudagrass (*Cynodon dactylon*) in fairways to postemergence herbicides applied at the Hoakalei Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). **Trial 1**: application dates – 12/21/16 and 01/31/17, rating dates – 12/30/16, 01/11/17, 01/31/17, 02/14/17, and 03/07/17. **Trial 2**: application dates – 06/20/17 and 08/01/17, rating dates – 06/27/17, 07/11/17, 07/25/17, 08/15/17, and 08/23/17. 3rd rating date not included, treatment not significant (P = 0.1035). Trial significant for 3rd rating date (P = 0.0015, F = 129.57): Trial 1 = 88.0 B, Trial 2 = 97.9 A (Means followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05). Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

Herbicide Treatment + MSO (2.0% v/v)***	Application Rate (kg ai/ha)	Trial	Green Color (%)*			
			1st Rating	2nd Rating**	4th Rating	5th Rating
		1	9DAS01	21DAS01	14DAS02	35DAS02
		2	7DAS01	21DAS01	14DAS02	22DAS02
1 Mesotrione + Ethofumesate	0.070 1.121	1	87.0 AB	37.5 B	82.0 A	98.8 A
		2	79.3 AB		51.3 B	93.3 C
2 Metribuzin + Ethofumesate	0.210 1.121	1	19.5 DE	13.1 CD	21.3 DEF	97.8 AB
		2	79.3 AB		28.8 CDE	94.0 C
3 Topramezone + Ethofumesate	0.025 1.121	1	77.5 AB	26.4 BC	39.3 BCD	98.3 A
		2	64.0 BC		43.8 BC	89.8 D
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.210 1.121	1	11.3 DE	9.4 CD	4.8 F	97.8
		2	39.3 CD		11.0 EF	93.0 CD
5 Topramezone + Metribuzin + Ethofumesate	0.025 0.210 1.121	1	5.0 E	7.6 D	2.3 F	97.8 AB
		2	20.5 DE		13.5 EF	93.8 C
6 Topramezone + Mesotrione + Ethofumesate	0.025 0.070 1.121	1	75.0 AB	17.1 CD	28.8 CDE	98.3 A
		2	64.8 BC		25.3 CDE	91.3 CD
7 Topramezone + Mesotrione + Metribuzin + Ethofumesate	0.025 0.070 0.210 1.121	1	5.5 E	15.6 CD	4.8 F	97.8 AB
		2	42 CD		13.3 EF	93.3 C
8 Untreated	-	1	99.0 A	97.3 A	97.5 A	97.3 AB
		2	97.5 A		96.0 A	94.5 BC
F value			8.57	60.3	5.81	4.05
P value			< 0.0001	< 0.0001	0.0001	0.0018

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** No trial and postemergence treatment interaction, data pooled over trial.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 13. Experiment 3. Response of seashore paspalum (*Paspalum vaginatum* 'Salam') greens to postemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). **Trial 1**: application dates – treatment a = 02/14/17 and 03/23/17, treatment b = 02/28/17 and 04/06/17, rating dates – 02/21/17, 02/28/17, 03/07/17, 03/14/17, 03/21/17, 03/28/17, 04/06/17, and 04/20/17. **Trial 2**: application dates – treatment a = 03/07/17 and 04/20/17, treatment b = 03/21/17 and 05/04/17, rating dates – 03/14/17, 03/21/17, 03/28/17, 04/06/17, 04/20/17, 04/27/17, 05/04/17, 05/18/17. 5th rating date, in both Trials 1 & 2, did not have a significant treatment effect, data not included. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

<table>
<tr><th rowspan="4">Herbicide Treatment
+
MSO (1.0% v/v)***</th><th rowspan="4">Application Rate
(kg ai/ha)</th><th rowspan="2">Trial</th><th colspan="7">Green Color (%)*</th></tr>
<tr><th>1st Rating</th><th>2nd Rating**</th><th>3rd Rating**</th><th>4th Rating**</th><th>6th Rating</th><th>7th Rating</th><th>8th Rating</th></tr>
<tr><td>1</td><td>7DAS01a</td><td>14DAS01a</td><td>21DAS01a,
7DAS01b</td><td>28DAS01a,
14DAS01b</td><td>42DAS01a,
28DAS01b,
5DAS02a</td><td>51DAS01a,
37DAS01b,
14DAS02a</td><td>65DAS01a,
51DAS01b,
28DAS02a,
14DAS02b</td></tr>
<tr><td>2</td><td>7DAS01a</td><td>14DAS01a</td><td>21DAS01a,
7DAS01b</td><td>30DAS01a,
16DAS01b</td><td>51DAS01a,
37DAS01b,
7DAS02a</td><td>58DAS01a,
44DAS01b,
14DAS2a</td><td>72DAS01a,
58DAS01b,
21DAS2a,
7DAS02b</td></tr>
<tr><td rowspan="2">1
a) Topramezone +
Metribuzin</td><td rowspan="2">0.012
0.105</td><td>1</td><td>80.8 B</td><td rowspan="2">84.9 B</td><td rowspan="2">94.5 A</td><td rowspan="2">96.6 A</td><td>77.8 D</td><td>86.5 B</td><td>90.5 C</td></tr>
<tr><td>2</td><td>72.0 C</td><td>87.5 C</td><td>94.3 A</td><td>96.0 A</td></tr>
<tr><td rowspan="2">2
a) Topramezone +
Metribuzin +
Ethofumesate

b) Ethofumesate</td><td rowspan="2">0.012
0.105
0.560

0.560</td><td>1</td><td>84.5 B</td><td rowspan="2">87.3 B</td><td rowspan="2">91.8 A</td><td rowspan="2">94.9 A</td><td>90.5 BC</td><td>93.5 A</td><td>92.8 ABC</td></tr>
<tr><td>2</td><td>82.0 B</td><td>95.5 AB</td><td>94.0 A</td><td>96.0 A</td></tr>
<tr><td rowspan="2">3
a) Topramezone +
Metribuzin +
Ethofumesate</td><td rowspan="2">0.012
0.105
1.121</td><td>1</td><td>83.5 B</td><td rowspan="2">87.3 B</td><td rowspan="2">92.5 A</td><td rowspan="2">96.3 A</td><td>88.5 C</td><td>95.0 A</td><td>91.8 BC</td></tr>
<tr><td>2</td><td>86.8 B</td><td>95.5 AB</td><td>96.0 A</td><td>95.8 AB</td></tr>
<tr><td rowspan="2">4
a) Ethofumesate

b) Mesotrione +
Metribuzin +
Ethofumesate</td><td rowspan="2">0.560

0.070
0.105
0.560</td><td>1</td><td>97 A</td><td rowspan="2">95.6 A</td><td rowspan="2">79.6 B</td><td rowspan="2">90.9 B</td><td>93.8 AB</td><td>94.0 A</td><td>86.5 D</td></tr>
<tr><td>2</td><td>97.3 A</td><td>96.8 A</td><td>94.8 A</td><td>94.3 ABC</td></tr>
<tr><td colspan="3">F value</td><td>4.96</td><td>16.4</td><td>40.32</td><td>27.63</td><td>3.84</td><td>6.51</td><td>3.28</td></tr>
<tr><td colspan="3">P value</td><td>0.011</td><td>< 0.0001</td><td>< 0.0001</td><td>< 0.0001</td><td>0.0275</td><td>0.0036</td><td>0.045</td></tr>
</table>

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** No trial and postemergence treatment interaction, data pooled over trial.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 14. Experiment 3. Response of bermudagrass (*Cynodon dactylon*) in greens to postemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). **Trial 1**: application dates – treatment a = 02/14/17 and 03/23/17, treatment b = 02/28/17 and 04/06/17, rating dates – 02/21/17, 02/28/17, 03/07/17, 03/14/17, 03/21/17, 03/28/17, 04/06/17, and 04/20/17. **Trial 2**: application dates – treatment a = 03/07/17 and 04/20/17, treatment b = 03/21/17 and 05/04/17, rating dates – 03/14/17, 03/21/17, 03/28/17, 04/06/17, 04/20/17, 04/27/17, 05/04/17, 05/18/17. 4^{th} and 5^{th} rating dates, in both Trials 1 & 2, did not have a significant treatment effect, data not included. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

Herbicide Treatment + MSO (1.0% v/v)***	Application Rate (kg ai/ha)	Trial	Green Color (%)*					
			1^{st} Rating**	2^{nd} Rating	3^{rd} Rating	6^{th} Rating	7^{th} Rating	8^{th} Rating
		1	7DAS01a	14DAS01a	21DAS01a, 7DAS01b	42DAS01a, 28DAS01b, 5DAS02a	51DAS01a, 37DAS01b 14DAS02a	65DAS01a, 51DAS01b, 28DAS02a, 14DAS02b
		2	7DAS01a	14DAS01a	21DAS01a, 7DAS01b	51DAS01a, 37DAS01b, 7DAS02a	58DAS01a, 44DAS01b, 14DAS02a	72DAS01a, 58DAS01b, 21DAS2a, 7DAS02b
1 a) Topramezone + Metribuzin	0.012 0.105	1	21.25 B	47.8 CD	71.8 A	36.0 B	94.5 A	96.3 A
		2		89.5 A	74.8 A	92.0 A	96.0 A	95.3 A
2 a) Topramezone + Metribuzin + Ethofumesate b) Ethofumesate	0.012 0.105 0.560 0.560	1	24.4 B	14.3 E	2.3 B	83.5 A	93.8 A	94.8 A
		2		63.3 BC	65.8 A	10.5 B	30.0 B	94.8 A
3 a) Topramezone + Metribuzin + Ethofumesate	0.012 0.105 1.121	1	28.3 B	7.0 E	1.3 B	79.8 A	94.0 A	95.3 A
		2		35 DE	81 A	7.0 B	13.3 C	96.3 A
4 a) Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	0.560 0.070 0.105 0.560	1	97.8 A	86.3 AB	4.5 B	91.8 A	91.5 A	95.0 A
		2		95.3 A	11.5 B	96.0 A	93.0 A	5.0 B
F value			180.16	6.08	11.61	119.06	234.58	3452.02
P value			< 0.0001	0.0048	0.0002	< 0.0001	< 0.0001	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** No trial and postemergence treatment interaction, data pooled over trial.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 15. Experiment 3. Response of goosegrass (*Eleusine indica*) in greens to postemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color), control rating (0 = no control, 100 = complete control). **Trial 1**: application dates – treatment a = 02/14/17 and 03/23/17, treatment b = 02/28/17 and 04/06/17, rating dates – 02/21/17, 02/28/17, 03/07/17, 03/14/17, 03/21/17, 03/28/17, 04/06/17, and 04/20/17. **Trial 2**: application dates – treatment a = 03/07/17 and 04/20/17, treatment b = 03/21/17 and 05/04/17, rating dates – 03/14/17, 03/21/17, 03/28/17, 04/06/17, 04/20/17, 04/27/17, 05/04/17, 05/18/17. Days after 1st and 2nd spray application (##DAS01, ## DAS02, respectively).

<table>
<tr><th rowspan="4">Herbicide Treatment
+
MSO (1.0% v/v)***</th><th rowspan="4">Application Rate
(kg ai/ha)</th><th rowspan="2">Trial</th><th colspan="3">Green Color (%)*</th><th colspan="5">Control (%)*</th></tr>
<tr><th>1st Rating</th><th>2nd Rating</th><th>3rd Rating</th><th>4th Rating**</th><th>5th Rating</th><th>6th Rating**</th><th>7th Rating</th><th>8th Rating</th></tr>
<tr><td>1</td><td>7DAS01a</td><td>14DAS01a</td><td>21DAS01a,
7DAS01b</td><td>28DAS01a,
14DAS01b</td><td>44DAS01a,
30DAS01b</td><td>42DAS01a,
28DAS01b,
5DAS02a</td><td>51DAS01a,
37DAS01b,
14DAS02a</td><td>65DAS01a,
51DAS01b,
28DAS02a,
14DAS02b</td></tr>
<tr><td>2</td><td>7DAS01a</td><td>14DAS01a</td><td>21DAS01a,
7DAS01b</td><td>30DAS01a,
16DAS01b</td><td>44DAS01a,
30DAS01b</td><td>51DAS01a,
37DAS01b,
7DAS02a</td><td>58DAS01a,
44DAS01b
14DAS2a</td><td>72DAS01a,
58DAS01b,
21DAS2a,
7DAS02b</td></tr>
<tr><td rowspan="2">1
a) Topramezone +
Metribuzin</td><td rowspan="2">0.012
0.105</td><td>1</td><td>2.3 D</td><td>1.0 B</td><td>0.0 B</td><td rowspan="2">93.5 A</td><td>99.8 A</td><td rowspan="2">95.3 A</td><td>99.0 A</td><td>100 A</td></tr>
<tr><td>2</td><td>16.3 BC</td><td>4.8 B</td><td>5.3 B</td><td>77.5 B</td><td>90.0 B</td><td>90.0 B</td></tr>
<tr><td rowspan="2">2
a) Topramezone +
Metribuzin +
Ethofumesate

b) Ethofumesate</td><td rowspan="2">0.012
0.105
0.560

0.560</td><td>1</td><td>3.3 D</td><td>1.0 B</td><td>0.0 B</td><td rowspan="2">92.8 A</td><td>99.5 A</td><td rowspan="2">94.9 A</td><td>99.0 A</td><td>100 A</td></tr>
<tr><td>2</td><td>27 B</td><td>5.5 B</td><td>8.8 B</td><td>75.8 B</td><td>88.3 B</td><td>89.3 B</td></tr>
<tr><td rowspan="2">3
a) Topramezone +
Metribuzin +
Ethofumesate</td><td rowspan="2">0.012
0.105
1.121</td><td>1</td><td>6.8 CD</td><td>2.0 B</td><td>0.0 B</td><td rowspan="2">90.5 A</td><td>99.5 A</td><td rowspan="2">95.4 A</td><td>99.0 A</td><td>100 A</td></tr>
<tr><td>2</td><td>26.5 B</td><td>5.8 B</td><td>9.0 B</td><td>78.8 B</td><td>90.0 B</td><td>89.0 B</td></tr>
<tr><td rowspan="2">4
a) Ethofumesate

b) Mesotrione +
Metribuzin +
Ethofumesate</td><td rowspan="2">0.560

0.070
0.105
0.560</td><td>1</td><td>98.8 A</td><td>96.3 A</td><td>85.5 A</td><td rowspan="2">1.3 B</td><td>1.3 C</td><td rowspan="2">1.3 B</td><td>1.0 C</td><td>1.0 C</td></tr>
<tr><td>2</td><td>97.5 A</td><td>92.8 A</td><td>72.0 A</td><td>2.0 C</td><td>1.0 C</td><td>1.0 C</td></tr>
<tr><td colspan="3">F value</td><td>10.32</td><td>6.22</td><td>11.47</td><td>462.56</td><td>16.35</td><td>2883.44</td><td>15.18</td><td>6.42</td></tr>
<tr><td colspan="3">P value</td><td>0.0004</td><td>0.0044</td><td>0.0002</td><td>< 0.0001</td><td>< 0.0001</td><td>< 0.0001</td><td>< 0.0001</td><td>0.0038</td></tr>
</table>

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** No trial and postemergence treatment interaction, data pooled over trial.

*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 16. Experiment 3. Number of goosegrass (*Eleusine indica*) present in 4.2m^2 part of treated plots, after postemergence herbicides were applied at the West Loch Golf Course. **Trial 1**: application dates – treatment a = 02/14/17 and 03/23/17, treatment b = 02/28/17 and 04/06/17. **Trial 2**: application dates – treatment a = 03/07/17 and 04/20/17, treatment b = 03/21/17 and 05/04/17. Rating date: 07/18/17 (117 days after start of trial 1 and 89 days after start of trial 2). No trial and postemergence treatment interaction, data pooled over trial.

Herbicide Treatment + MSO (1% v/v)**	Application Rate (kg ai/ha)	Number of goosegrass*
1 a) Topramezone + Metribuzin	 0.012 0.105	2.8 B
2 a) Topramezone + Metribuzin + Ethofumesate b) Ethofumesate	 0.012 0.105 0.560 0.560	2.2 B
3 a) Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121	4.0 B
4 a) Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.560 0.070 0.105 0.560	30.4 A
F value		13.86
P value		0.0001

* Means within column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 17. Experiment 4. Evaluation of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') fairways to postemergence herbicides applied at the Hoakalei Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application date – 08/01/17. Days after 1st spray (##DAS01).

Herbicide Treatment + MSO (2.0% v/v)**	Application Rate (kg ai/ha)	Dates for Visual Green Color Ratings (%)*		
		08/08/17 7DAS01	08/15/17 14DAS01	08/23/17 22DAS01
1 Mesotrione	0.070	72.0 B	88.8 BC	94.5 A
2 Mesotrione + Metribuzin	0.070 0.210	84.3 AB	94.3 AB	95.5 A
3 Mesotrione + Ethofumesate	0.070 1.121	81.8 AB	85.5 CD	91.0 AB
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.210 1.121	83.5 AB	96.5 A	95.8 A
5 Topramezone	0.025	41.0 C	22.5 E	93.5 A
6 Topramezone + Metribuzin	0.025 0.210	80.8 AB	95.3 A	95.5 A
7 Topramezone + Ethofumesate	0.025 1.121	77.5 AB	80.0 D	87.0 B
8 Topramezone + Metribuzin + Ethofumesate	0.025 0.210 1.121	78.5 AB	93.8 AB	94.0 A
9 Untreated	-	96.3 A	96.3 A	94.8 A
F value		9.96	311.61	7.65
P value		< 0.0001	< 0.0001	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 18. Experiment 5. Response of seashore paspalum (SP) (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (BG) (*Cynodon dactylon*) turf grown in containers to postemergence herbicides applied at the Magoon Research Station. Green color rating (0 = brown/white, 100 = maximum attainable green color). **Trial 1**: application date – 09/29/17, rating dates – 10/06/17, 10/13/17, 10/20/17, and 10/27/17. **Trial 2**: application date – 10/13/17, rating dates – 10/20/17, 10/27/17, 11/03/17, and 11/10/17. 4th rating date not included, all treatments and species recovered to pre-spray condition. Days after 1st spray (##DAS01).

Herbicide Treatment + MSO (1% v/v)	Application Rate (kg ai/ha)	Trial	Green Color (%)*					
			1st Rating 7DAS01		2nd Rating 14DAS01		3rd Rating 21DAS01	
			SP	BG	SP	BG	SP	BG
1 Mesotrione	0.070	1	85.2 ABC	93.8 AB	85.8 ABCD	94.8 ABC	97.8 A	97.8 A
		2	15.5 JKL	93.3 AB	57.5 FG	95.8 ABC	93.3 ABCDE	97.0 AB
2 Mesotrione + Metribuzin	0.070 0.105	1	87.8 AB	92.3 AB	86.8 ABCD	95.0 ABC	97.0 AB	97.8 A
		2	40.5 GHI	91.5 AB	83.3 ABCDE	96.5 AB	97.0 AB	96.8 AB
3 Mesotrione + Ethofumesate	0.070 1.121	1	91.5 AB	77.0 BCD	90.8 ABCD	76.5 CDEF	97.8 A	97.8 A
		2	49.5 FGH	65.5 DEF	73.8 DEF	82.5 ABCDE	96.3 ABC	97.3 AB
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.105 1.121	1	60.5 DEF	23.3 IJK	37.5 HIJK	17.3 LM	91 CDEF	95.5 ABCD
		2	76.8 BCD	32.5 HIJ	47.5 GHIJ	21.3 KLM	88.5 EF	90.5 DEF
5 Topramezone	0.012	1	16.8 JKL	20.3 JKL	23.0 KL	82.0 ABCDE	93.3 ABCDE	97.0 AB
		2	4.25 L	19.5 JKL	2.8 M	76.5 CDEF	87.0 F	97.3 AB
6 Topramezone + Metribuzin	0.012 0.105	1	17.5 JKL	22.5 IJKL	46.5 EFG	81.5 ABCDE	96.5 AB	96.8 AB
		2	13.8 KL	17.3 JKL	51.8 GHI	80.3 ABCDE	95.0 ABCD	97.5 AB
7 Topramezone + Ethofumesate	0.012 1.121	1	68.3 CDE	26.8 IJK	72.8 DEF	19.8 KLM	97.0 AB	95.5 ABCD
		2	16.3 JKL	31.3 HIJK	32.5 IJKL	29.5 JKL	92.3 BCDEF	97.5 AB
8 Topramezone + Metribuzin + Ethofumesate	0.012 0.105 1.121	1	62.5 DEF	16.8 JKL	78.8 ABCDE	37.5 HIJK	93.0 ABCDE	95.3 ABCD
		2	53.8 EFG	33.8 HIJ	77.8 BCDE	52.5 GH	96.8 AB	97.3 AB
9 Metribuzin	0.105	1	88.0 AB	93.0 AB	87.0 ABCD	95.0 ABC	95.8 ABCD	97.8 A
		2	96.3 A	96.5 A	94.8 ABC	97.0 AB	97.3 AB	96.8 AB
10 Untreated	-	1	97.0 A	97.0 A	97.0 AB	97.0 AB	98.0 A	97.5 AB
		2	97.8 A	97.3 A	97.3 A	97.5 A	97.8 A	96.5 AB
F value			16.79		6.47		3.37	
P value			< 0.0001		< 0.0001		0.0011	

* Means in rows and columns within the rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 19. Experiment 5. Dry weights of seashore paspalum (SP) (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (BG) (*Cynodon dactylon*) clippings 21 days after postemergence herbicides were applied at the Magoon Research Station. **Trial 1**: application date – 09/29/17, clippings collected 10/20/17. **Trial 2**: application date – 10/13/17, clippings collected 11/03/17. Clippings collected 21 days after spray application (DAS). Trial and species interaction is significant (P = 0.033, F = 4.66): Trial 1 X BG = 1.57 A, Trial 2 X BG = 1.60 A, Trial 1 X SP = 0.80 B, Trial 2 SP = 1.10 B (Means followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05). Initial (pre-spray) clipping weight used as a covariant (P = 0.0001, T = 3.98). Days after 1st spray (##DAS01).

Herbicide Treatment + MSO (1% v/v)***	Application Rate (kg ai/ha)	Clippings (g)			
		21DAS01			
		Species*		Trial**	
		SP	BG	1	2
1 Mesotrione	0.070	1.05 EFGH	2.03 ABC	1.45 ABCDEF	1.63 ABCD
2 Mesotrione + Metribuzin	0.070 0.105	1.16 DEFG	2.29 A	1.64 ABCD	1.81 ABC
3 Mesotrione + Ethofumesate	0.070 1.121	0.92 EFGH	1.36 CDEF	1.02 DEFG	1.26 CDEFG
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.105 1.121	0.41 H	0.58 GH	0.70 GH	0.29 H
5 Topramezone	0.012	0.67 GH	1.84 ABCD	1.32 BCDEFG	1.18 CDEFG
6 Topramezone + Metribuzin	0.012 0.105	0.96 EFGH	1.78 ABCD	1.25 CDEFG	1.50 ABCDE
7 Topramezone + Ethofumesate	0.012 1.121	0.71 FGH	0.71 FGH	0.66 GH	0.76 FGH
8 Topramezone + Metribuzin + Ethofumesate	0.012 0.105 1.121	0.88 EFGH	1.01 EFGH	0.92 EFGH	0.97 DEFGH
9 Metribuzin	0.105	1.22 DEFG	2.14 AB	1.35 BCDEFG	2.01 AB
10 Untreated	-	1.51 BCDE	2.12 AB	1.53 ABCDE	2.09 A
F value		5.34		2.64	
P value		< 0.0001		0.0083	

* Means in rows and columns within species column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** Means in rows and columns within trial column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 20. Experiment 5. Dry weights of seashore paspalum (SP) (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (BG) (*Cynodon dactylon*) shoots after postemergence herbicides were applied at the Magoon Research Station. **Trial 1**: application date – 09/29/17, shoots collected 11/27/17. **Trial 2**: application date – 10/13/17, shoots collected 12/11/17. Shoots collected 59 days after spray application (DAS). No significant interactions for treatment factors, data pooled over species and trials. Days after 1st spray (##DAS01).

Herbicide Treatment + MSO (1% v/v)**	Application Rate (kg ai/ha)	Shoots (g)*
		59DAS01
1 Mesotrione	0.070	8.45 AB
2 Mesotrione + Metribuzin	0.070 0.105	8.02 ABC
3 Mesotrione + Ethofumesate	0.070 1.121	7.75 ABC
4 Mesotrione + Metribuzin + Ethofumesate	0.070 0.105 1.121	7.26 BC
5 Topramezone	0.012	7.87 ABC
6 Topramezone + Metribuzin	0.012 0.105	7.69 ABC
7 Topramezone + Ethofumesate	0.012 1.121	7.20 BC
8 Topramezone + Metribuzin + Ethofumesate	0.012 0.105 1.121	7.06 C
9 Metribuzin	0.105	7.88 ABC
10 Untreated	-	8.60 A
F value		3.08
P value		0.0024

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 21. Experiment 6. Response of seashore paspalum (*Paspalum vaginatum* 'Salam') greens to postemergence and preemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. All treatments recovered to pre-spray condition by 08/28/17. No postemergence and preemergence herbicide treatment interaction, data pooled over preemergence herbicide. On rating date 08/15/17, preemergence herbicide treatment (0.841 kg oxadiazon/ha) significant (P = 0.0007, F = 30.33): untreated = 94.2 A, Anderson's Goosegrass/Crabgrass = 91.8 B, Ronstar = 89.8 C (Means followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05). Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1.0% v/v)**	Application Rate (kg ai/ha)	Dates for Visual Green Color Ratings (%)*				
		07/18/17	07/25/17	08/01/17	08/08/17	08/15/17
		7DAS01	14DAS01	7DAS02	14DAS02, 7DAP01	21DAS02, 7DAP02
POST 1 a) Mesotrione + Metribuzin + Ethofumesate b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	87.5 B	91.3 B	85.3 AB	86.0 A	93.0 AB
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	87.5 B	90.8 BC	71.5 BC	71.2 B	91.2 BC
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	70.3 D	86.5 D	63.5 C	70.8 B	90.4 BC
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	74.3 C	88.0 CD	63.5 C	65.5 B	88.5 C
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	97.8 A	95.3 A	82.0 AB	87.2 A	93.4 AB
POST 6 Untreated	-	97.5 A	96.5 A	94.8 A	93.7 A	95.1 A
F value		263.17	41.68	14.45	13.46	12.94
P value		< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 22. Experiment 6. Response of bermudagrass (*Cynodon dactylon*) in greens to postemergence and preemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. All treatments recovered to pre-spray condition by 08/28/17. No postemergence and preemergence herbicide treatment interaction and preemergence herbicide treatment not significant, data pooled over preemergence herbicide. Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1.0% v/v)**	Application Rate (kg ai/ha)	Dates for Visual Green Color Ratings (%)*				
		07/18/17	07/25/17	08/01/17	08/08/17	08/15/17
		7DAS01	14DAS01	7DAS02	14DAS02, 7DAP01	21DAS02, 7DAP02
POST 1 a) Mesotrione + Metribuzin + Ethofumesate b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	19.3 B	11.5 B	2.0 C	1.0 B	3.8 C
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	17.0 B	12.3 B	1.5 C	1.0 B	1.0 C
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	15.0 B	7.0 B	1.5 C	1.0 B	1.5 C
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	15.8 B	6.8 B	1.5 C	1.0 B	1.0 C
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	97.5 A	96.5 A	8.25 B	0.9 B	15.3 B
POST 6 Untreated	-	97.3 A	96.8 A	95.0 A	94.3 A	95.2 A
F value		506.82	1118.95	7121.03	182745	866.48
P value		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 23. Experiment 6. Response of goosegrass (*Eleusine indica*) in greens to postemergence and preemergence herbicides applied at the West Loch Golf Course. Green color rating (0 = brown/white, 100 = maximum attainable green color). Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1% v/v)	Application Rate (kg ai/ha)	Preemergence Herbicide****	Dates for Visual Green Color Ratings (%)*				
			07/18/17**	07/25/17**	08/01/17**	08/08/17	08/15/17**
			7DAS01	14DAS01	7DAS02	14DAS02, 7DAP01	21DAS02, 7DAP02
POST 1 a) Mesotrione + Metribuzin + Ethofumesate b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	Untreated	72.3 B	93.5 A	4.3 C	0.0 C	0.0 C
		Anderson's Goosegrass/ Crabgrass				0.0 C	
		Ronstar® Flo				0.0 C	
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	Untreated	72.3 B	94.3 A	1.5 C	0.0 C	0.0 C
		Anderson's Goosegrass/ Crabgrass				0.0 C	
		Ronstar® Flo				0.0 C	
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	Untreated	33.3 C	2.3 B	1.0 C	0.0 C	0.0 C
		Anderson's Goosegrass/ Crabgrass				0.0 C	
		Ronstar® Flo				0.0 C	
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	Untreated	30.8 C	1.8 B	1.0 C	0.0 C	0.0 C
		Anderson's Goosegrass/ Crabgrass				0.0 C	
		Ronstar® Flo				0.0 C	
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	Untreated	96.0 A	95.8 A	12.3 B	1.5 C	20.8 B
		Anderson's Goosegrass/ Crabgrass				0.8 C	
		Ronstar® Flo				0.8 C	
POST 6 Untreated	-	Untreated	95.3 A	95.5 A	95.5 A	94.3 A	93.6 A
		Anderson's Goosegrass/ Crabgrass				94.3 A	
		Ronstar® Flo				91.3 B	
F value			120.53	3442.08	2678.87	4.49	1222.69
P value			< 0.0001	< 0.0001	< 0.0001	0.0007	< 0.0001

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** No postemergence and preemergence herbicide treatment interaction, preemergence herbicide data pooled.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.
**** Anderson's Goosegrass/Crabgrass (3.360 kg bensulide/ha and 0.841 kg oxadiazon), Ronstar® Flo (0.841 kg oxadiazon).

Table 24. Experiment 6. Percent of seashore paspalum (*Paspalum vaginatum* 'Salam') covering the plot after postemergence and preemergence herbicides were applied at the West Loch Golf Course. Percent cover rating (0 = no grass present, 100 = grass filled the plot). Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1% v/v)**	Application Rate (kg ai/ha)	Preemergence Herbicide ***	Seashore Paspalum Cover (%)*	
			08/28/17 34DAS02, 20DAP02	09/13/17 50DAS02, 36DAP02
POST 1 a) Mesotrione + Metribuzin + Ethofumesate b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	Untreated	97.0 A	100 A
		Anderson's Goosegrass/ Crabgrass	94.0 A	100 A
		Ronstar® Flo	85.5 AB	99.5 A
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	Untreated	84.5 AB	99.8 A
		Anderson's Goosegrass/ Crabgrass	67.0 ABC	96.0 ABC
		Ronstar® Flo	62.0 ABC	96.0 ABC
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	Untreated	82.8 ABC	99.5 A
		Anderson's Goosegrass/ Crabgrass	78.3 ABC	97.0 AB
		Ronstar® Flo	51.5 BC	89.8 C
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	Untreated	82.5 ABC	99.3 A
		Anderson's Goosegrass/ Crabgrass	45.3 C	90.5 C
		Ronstar® Flo	45.0 C	91.0 BC
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	Untreated	94.5 A	100 A
		Anderson's Goosegrass/ Crabgrass	91.5 A	99.8 A
		Ronstar® Flo	91.5 A	99.5 A
POST 6 Untreated	-	Untreated	99.0 A	100 A
		Anderson's Goosegrass/ Crabgrass	98.5 A	100 A
		Ronstar® Flo	98.5 A	100 A
F value			2.41	4.56
P value			0.0307	0.0006

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.

** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

*** Anderson's Goosegrass/Crabgrass (3.360 kg bensulide/ha and 0.841 kg oxadiazon), Ronstar® Flo (0.841 kg oxadiazon).

Table 25. Experiment 6. Percent change of goosegrass (*Eleusine indica*) counts after postemergence and preemergence herbicides were applied at the West Loch Golf Course. Application dates – postemergence herbicide treatment a = 07/11/17, postemergence herbicide treatment b = 07/25/17, preemergence herbicide = 08/01/17 and 08/08/17. No postemergence and preemergence herbicide treatment interaction and preemergence herbicide treatment not significant, data pooled over preemergence herbicide. Days after 1st and 2nd spray application (##DAS01, ## DAS01, respectively). Days after 1st and 2nd preemergence application (##DASP01, ##DASP02, respectively).

Postemergence Herbicide Treatment (POST) + MSO (1% v/v)***	Application Rate (kg ai/ha)	Goosegrass Counts		Percent Change*
		07/11/17**	10/09/17*	
		Day 0	90DAS01, 76DAS02 69DAP01, 62DAP02	
POST 1 a) Mesotrione + Metribuzin + Ethofumesate b) Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.012 0.105 1.121	15.8	13.3 B	-32.6 B
POST 2 a) Mesotrione + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.105 1.121 0.070 0.012 0.105 1.121	20.9	14.7 B	-25.6 B
POST 3 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.105 1.121	17.8	12.6 B	-25.6 B
POST 4 a) Topramezone + Metribuzin + Ethofumesate b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.012 0.105 1.121 0.070 0.012 0.105 1.121	20.1	4.8 B	-74.5 B
POST 5 a) Untreated b) Mesotrione + Topramezone + Metribuzin + Ethofumesate	 0.070 0.012 0.105 1.121	14.3	14.4 B	35.5 AB
POST 6 Untreated	-	18.8	38.4 A	104.7 A
F value		0.58	16.7	5.66
P value		0.712	< 0.0001	0.004

* Means within rating sequence column followed by the same letters are not significantly different as determined by Tukey HSD at P<0.05.
** Counts prior to the start of herbicide applications.
*** All treatments received MSO, methylated seed oil, added for enhanced foliar penetration.

Table 26. Best management practice incorporating bermudagrass (*Cynodon dactylon*) suppression and goosegrass (*Eleusine indica*) control with seashore paspalum (*Paspalum vaginatum*) greens renovation. Experimental procedures justify support changes in herbicide product labels for use in Hawaii and currently (as of 2018) are not legal in Hawaii.

<table>
<tr><td colspan="2">Provide maximize turf vigor with optimum nutrition and moisture levels to enhance post spray turf recovery</td></tr>
<tr><th>Treatment</th><th>Formulated product (kg ai/ha)</th></tr>
<tr><td>POST A
Mesotrione +
Metribuzin +
Ethofumesate +
MSO (1.0% v/v)*</td><td>
0.070
0.105
1.121
</td></tr>
<tr><td colspan="2">2 weeks with normal irrigation - bermudagrass suppression initiated</td></tr>
<tr><th>Treatment</th><th>Formulated product (kg ai/ha)</th></tr>
<tr><td>POST B
Topramezone +
Metribuzin +
Ethofumesate +
MSO (1.0% v/v)*</td><td>
0.012
0.105
1.121
</td></tr>
<tr><td colspan="2">3-5 day dry down for goosegrass removal then restore normal irrigation</td></tr>
<tr><td colspan="2">Rehydrate greens to allow for solid soil core extraction with aeration tool</td></tr>
<tr><td colspan="2">Core aeration/verticut/top dress/brush in sand/fertilizer, 1-2 days</td></tr>
<tr><td colspan="2">1st application (0.841 kg ai/ha) of oxadiazon (as Anderson’s Goosegrass/
Crabgrass or Ronstar® Flo)** - water in 10-15 min. immediately after herbicide application</td></tr>
<tr><td colspan="2">5-7 days, possibly shorter</td></tr>
<tr><td colspan="2">2nd application (0.841 kg ai/ha) of oxadiazon (as Anderson’s Goosegrass/
Crabgrass or Ronstar® Flo)** - water in 10-15 min. immediately after herbicide application</td></tr>
</table>

* Methylated seed oil, added for enhanced foliar penetration.
** ½ Rate rates of recommended amounts of trade name products.

Figure 1. Single nozzle boom spray application treatment plot. Treated area (left of red line) - 0.91 m wide, buffer zone (right of red line) - 0.30 m.

Figure 2. Seashore paspalum (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (*Cynodon dactylon*) growth prior to initial herbicide application.

Figure 3. Herbicide treatments applied in a shrouded box to prevent drift and maintain boom height above turf pots.

Figure 4. Turf cut to the top of the pot during clipping collection. Clipped turf (left) and Pre-clipped turf (right).

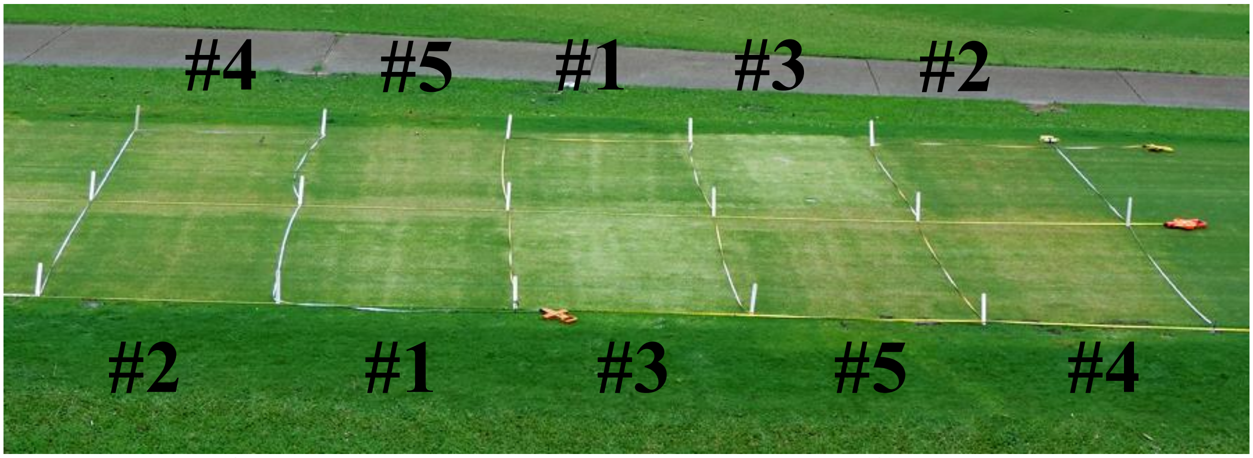

Figure 5. Response of seashore paspalum (*Paspalum vaginatum* 'Salam') 7 days after initial herbicide application at the Pali Golf Course. The addition of metribuzin to tank mix reduced mesotrione and topramezone foliar bleaching (#1 vs #2 and #3 vs #4, respectfully). Treatment 1 – mesotrione, treatment 2 – mesotrione + metribuzin, treatment 3 – topramezone, treatment 4 – topramezone + metribuzin, treatment 5 – mesotrione + topramezone + metribuzin.

Figure 6. Response of seashore paspalum (*Paspalum vaginatum* 'Salam') 7 days after second herbicide application at the Pali Golf Course. Excessive seashore paspalum injury in treatments 4 and 5. Treatment 3 did not receive a second application due to excessive injury following the initial application. Treatment 1 – mesotrione, treatment 2 – mesotrione + metribuzin, treatment 3 – topramezone, treatment 4 – topramezone + metribuzin, treatment 5 – mesotrione + topramezone + metribuzin.

Figure 7. Response of goosegrass (*Eleusine indica*) 7 days after second herbicide application at the Pali Golf Course. Only treatments 4 and 5 provided goosegrass control, significant seashore paspalum injury occurred. Treatment 4 – topramezone + metribuzin, treatment 5 – mesotrione + topramezone + metribuzin.

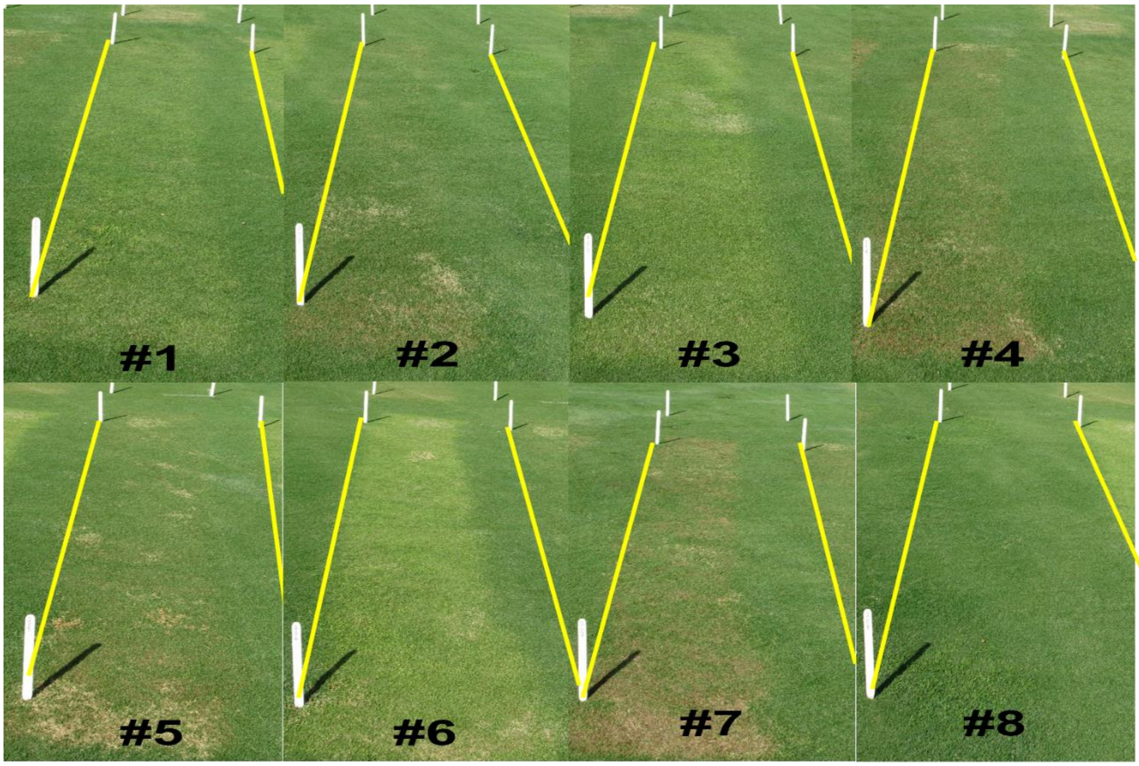

Figure 8. Response of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') 14 days after second herbicide application, trial 1, at the Hoakalei Country Club. The addition of metribuzin to tank mix safened seashore paspalum discoloration (#1 vs #4, #3 vs #5, and #6 vs #7). Brown discoloration within plots is bermudagrass (*Cynodon dactylon*) injury. Treatment 1 – mesotrione + ethofumesate, treatment 2 – metribuzin + ethofumesate, treatment 3 – topramezone + ethofumesate, treatment 4 – mesotrione + metribuzin + ethofumesate, treatment 5 – topramezone + metribuzin + ethofumesate, treatment 6 – topramezone + mesotrione + ethofumesate, treatment 7 – topramezone + mesotrione + metribuzin + ethofumesate, treatment 8 – untreated.

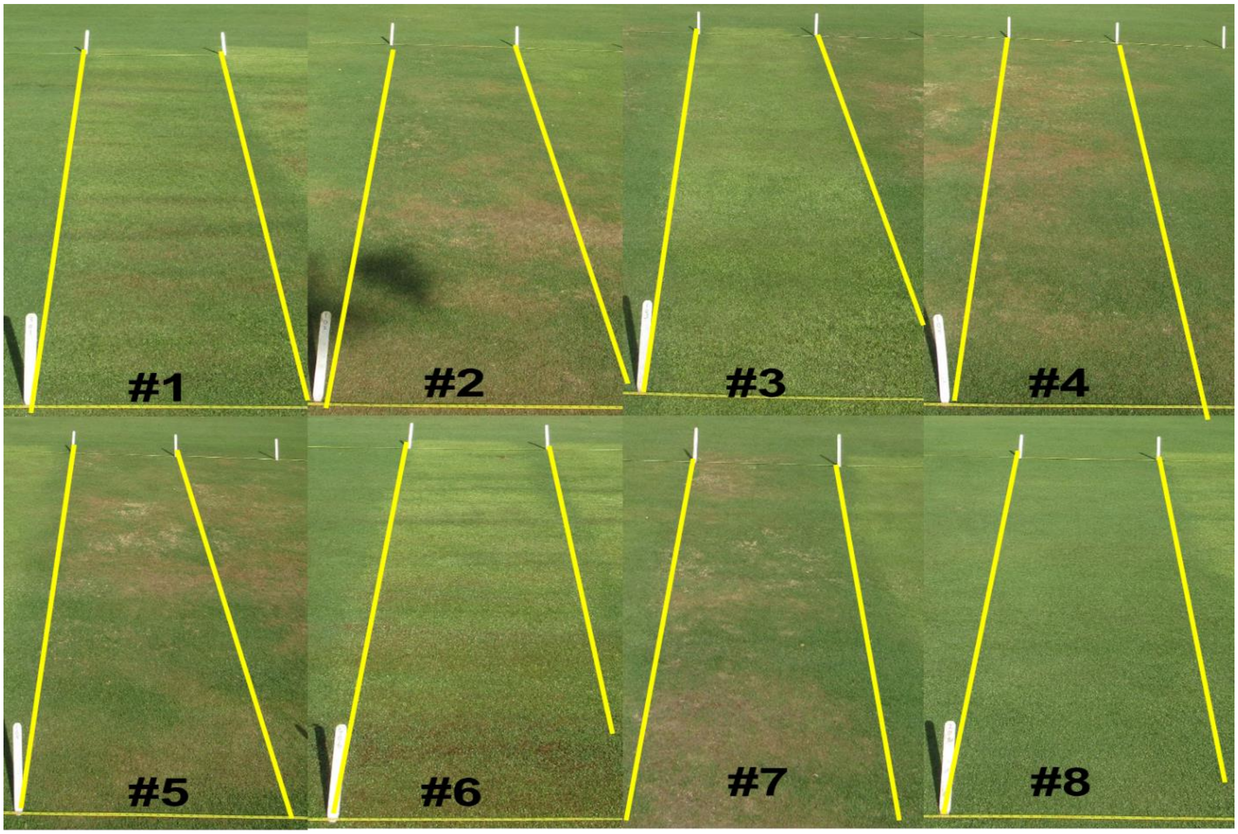

Figure 9. Response of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') 14 days after second herbicide application, trial 2, at the Hoakalei Country Club. The addition of metribuzin to tank mix safened seashore paspalum discoloration (#1 vs #4, #3 vs #5, and #6 vs #7). Brown discoloration within plots is bermudagrass (*Cynodon dactylon*) injury. Treatment 1 – mesotrione + ethofumesate, treatment 2 – metribuzin + ethofumesate, treatment 3 – topramezone + ethofumesate, treatment 4 – mesotrione + metribuzin + ethofumesate, treatment 5 – topramezone + metribuzin + ethofumesate, treatment 6 – topramezone + mesotrione + ethofumesate, treatment 7 – topramezone + mesotrione + metribuzin + ethofumesate, treatment 8 – untreated.

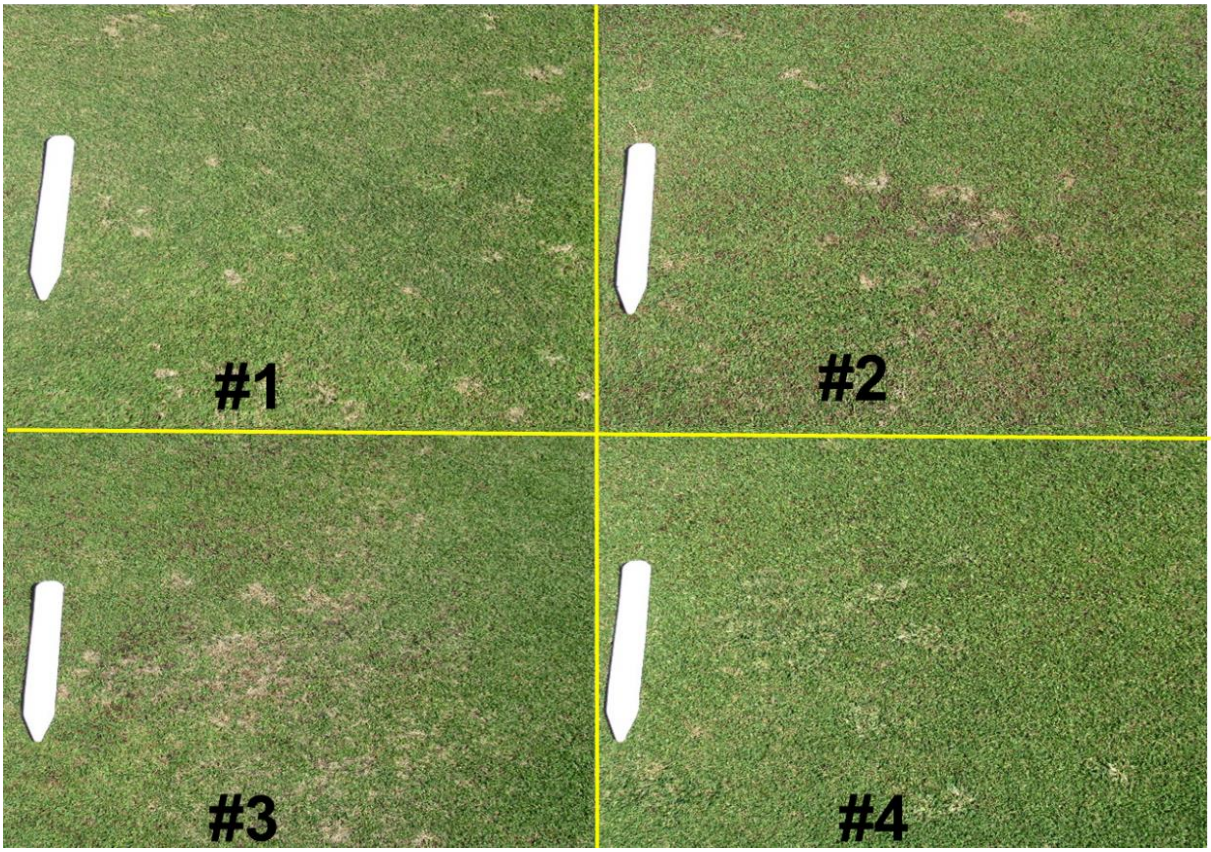

Figure 10. Response of goosegrass (*Eleusine indica*) 21 days after initial herbicide application, trial 1, at the West Loch Golf Course. Treatments 1, 2, and 3 provided complete control of goosegrass; treatment 4 had no long-term impact on goosegrass. Treatment 1 – topramezone + metribuzin, treatment 2 – topramezone + metribuzin + ethofumesate followed by ethofumesate, treatment 3 – topramezone + metribuzin + ethofumesate, treatment 4 – ethofumesate followed by mesotrione + metribuzin + ethofumesate.

Figure 11. Response of goosegrass (*Eleusine indica*) 21 days after initial herbicide application, trial 2, at the West Loch Golf Course. Treatments 1, 2, and 3 caused significant goosegrass, but goosegrass still growing at the tips. Treatment 4 had no long-term impact on goosegrass. Treatment 1 – topramezone + metribuzin, treatment 2 – topramezone + metribuzin + ethofumesate followed by ethofumesate, treatment 3 – topramezone + metribuzin + ethofumesate, treatment 4 – ethofumesate followed by mesotrione + metribuzin + ethofumesate.

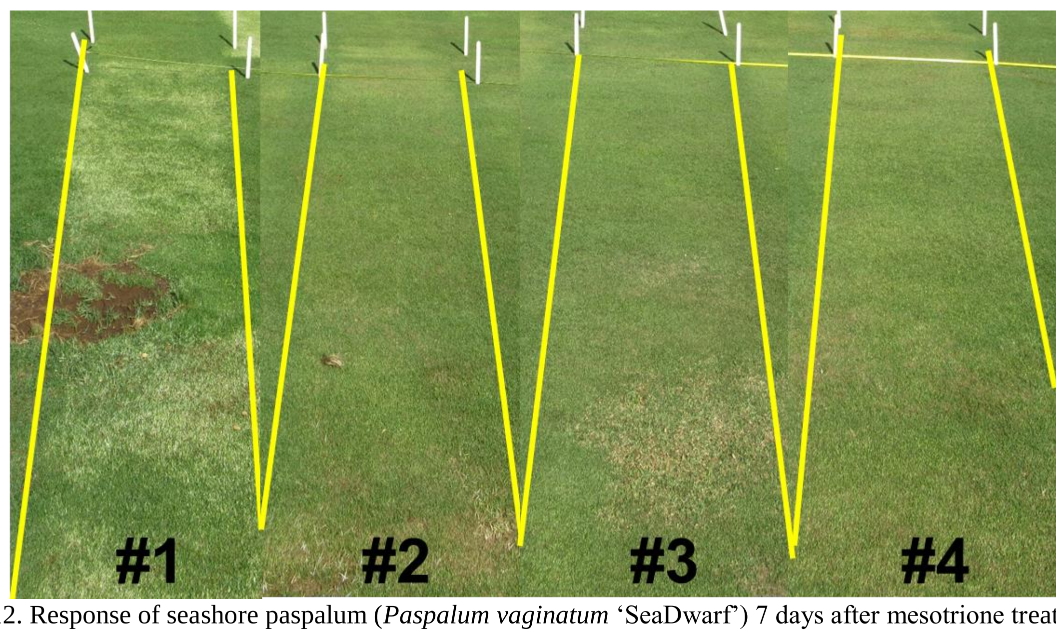

Figure 12. Response of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') 7 days after mesotrione treatments at the Hoakalei Country Club. The addition of metribuzin and/or ethofumesate reduced mesotrione bleaching. Treatment 1 – mesotrione, treatment 2 – mesotrione + metribuzin, treatment 3 – mesotrione + ethofumesate, treatment 4 – mesotrione + metribuzin + ethofumesate.

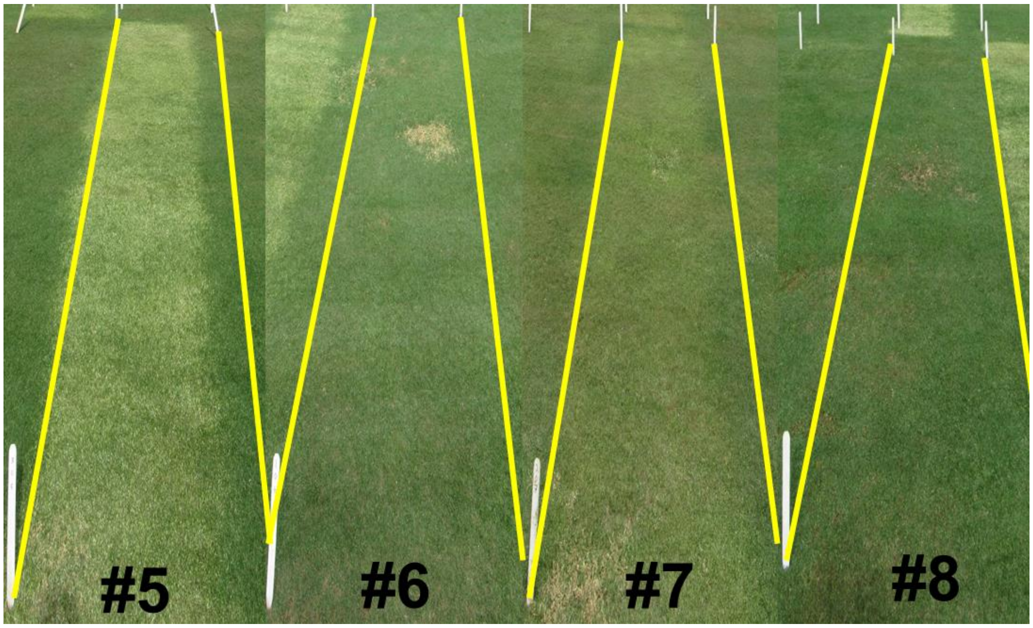

Figure 13. Response of seashore paspalum (*Paspalum vaginatum* 'SeaDwarf') 14 days after topramezone treatments at the Hoakalei Country Club. The addition of metribuzin and/or ethofumesate reduced mesotrione bleaching. Treatment 5 – topramezone, treatment 6 – topramezone + metribuzin, treatment 7 – topramezone + ethofumesate, treatment 8 – topramezone + metribuzin + ethofumesate.

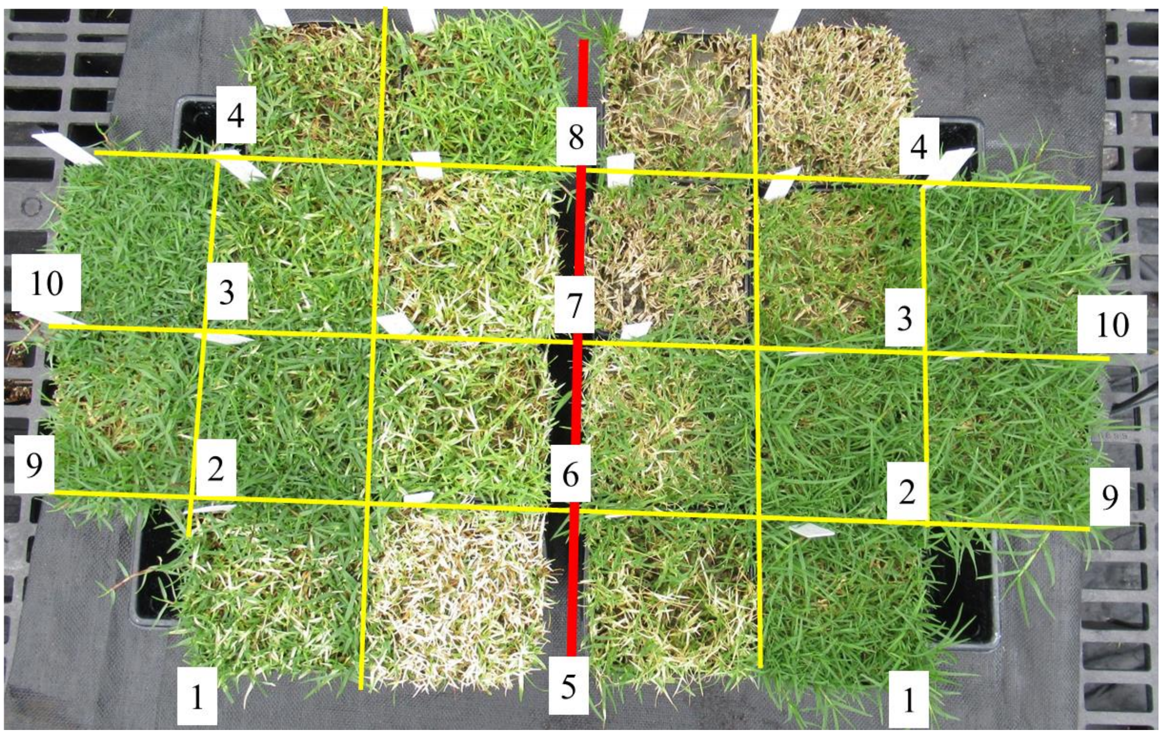

Figure 12. Response of seashore paspalum (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (*Cynodon dactylon*) 14 days after herbicide treatments, trial 2, at the Magoon Research Station. Seashore paspalum is on the left of the red line and bermudagrass is on the right. Treatment 1 – mesotrione, treatment 2 – mesotrione + metribuzin, treatment 3 – mesotrione + ethofumesate, treatment 4 – mesotrione + metribuzin + ethofumesate, treatment 5 – topramezone, treatment 6 – topramezone + metribuzin, treatment 7 – topramezone + ethofumesate, treatment 8 – topramezone + metribuzin + ethofumesate, treatment 9 – metribuzin, treatment 10 - untreated.

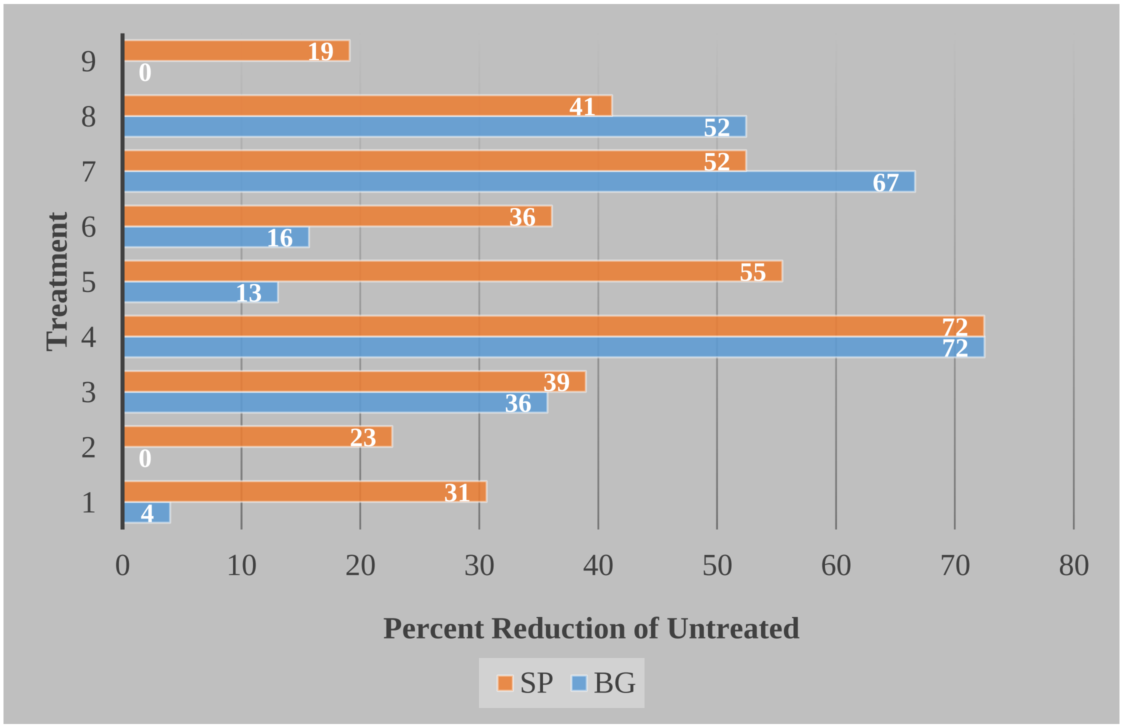

Figure 13. Seashore paspalum (SP) (*Paspalum vaginatum* 'SeaStar') and common bermudagrass (BG) (*Cynodon dactylon*) clipping dry weight percent reduction of untreated 21 days after herbicide application at the Magoon Research Station. The percent reduction of untreated was derived using the equation ((untreated dry weight – treatment dry weight)/untreated dry weight)) x 100 (see Table 19 for complete data set). Data not subjected to ANOVA and only provided for ease of comparisons for species response to treatments. Bermudagrass values missing from treatment 2 and 9 due to no growth reduction in comparison to untreated plants. Treatment 1 – mesotrione, treatment 2 – mesotrione + metribuzin, treatment 3 – mesotrione + ethofumesate, treatment 4 – mesotrione + metribuzin + ethofumesate, treatment 5 – topramezone, treatment 6 – topramezone + metribuzin, treatment 7 – topramezone + ethofumesate, treatment 8 – topramezone + metribuzin + ethofumesate, treatment 9 – metribuzin.

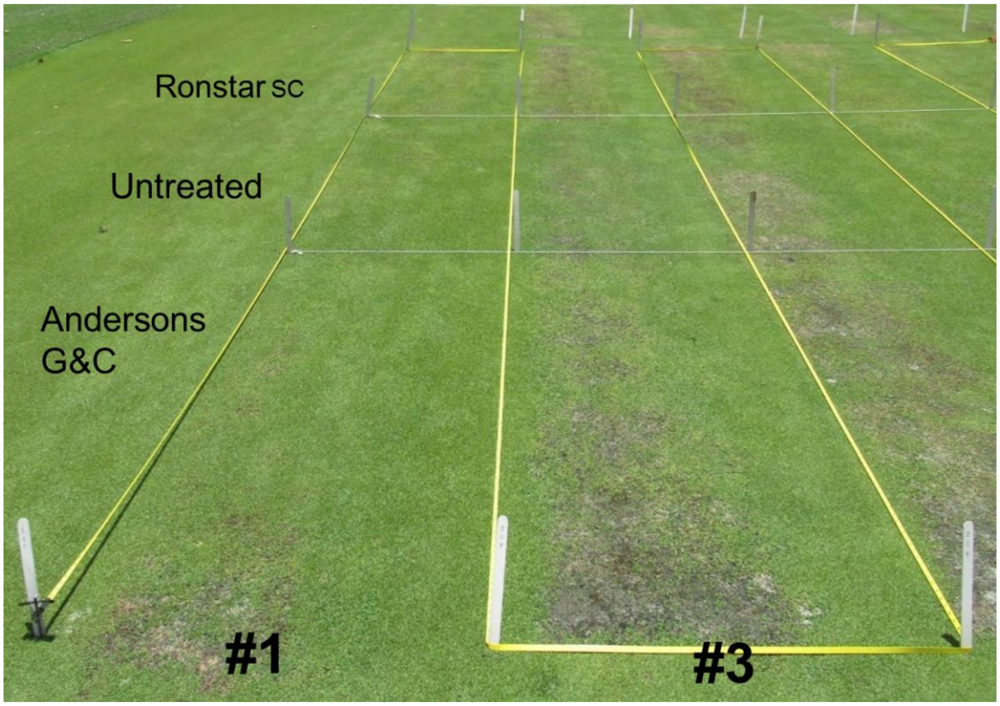

Figure 14. Response of seashore paspalum (*Paspalum vaginatum* ‘Salam’) 21 days after the final postemergence herbicide application (7 days after final preemergence herbicide application) at the West Loch Golf Course. Treatment 3 resulted in more seashore paspalum injury compared to treatment. Both received the same amount of chemicals, applied in different sequence. Post 1 – mesotrione + metribuzin + ethofumesate followed by topramezone + metribuzin + ethofumesate, post 3 – topramezone + metribuzin + ethofumesate followed by mesotrione + metribuzin + ethofumesate.

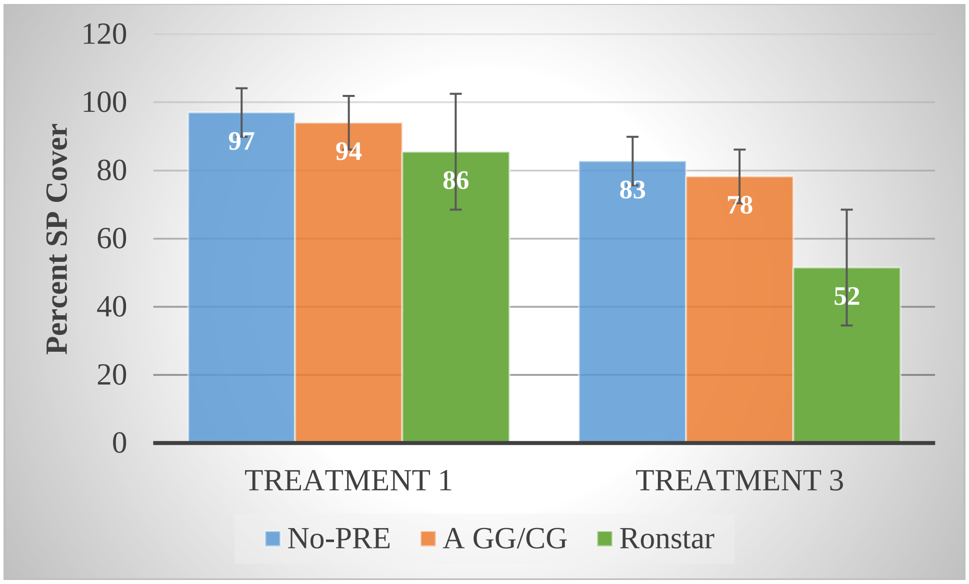

Figure 15. Percent of seashore paspalum (*Paspalum vaginatum* 'Salam') covering the treatment plot 20 days after the final preemergence herbicide application at the West Loch Golf Course. Treatments with standard error bars (95% confidence interval) overlapping are not significantly different from each other. The liquid formulation of oxadiazon (Ronstar) delay turf recovery compared to the granular formulation (Anderson’s Goosegrass/Crabgrass control – A GG/CG). Post 1 – mesotrione + metribuzin + ethofumesate followed by topramezone + metribuzin + ethofumesate, post 3 – topramezone + metribuzin + ethofumesate followed by mesotrione + metribuzin + ethofumesate.

Figure 18. Core aeration during a greens renovation. A = aeration machines extracting soil cores, B = solid core extraction in a well-hydrated green, C = solid soil cores collected and removed from green.

Figure 19. Top dressing, brushing in the sand, and fertilization during greens renovation. A = green top-dressed with sand and being brushed in, B = close up of a device used to brush in the sand, C = green with sand brushed into core aeration holes, D = fertilizer applied to aid turf recovery.

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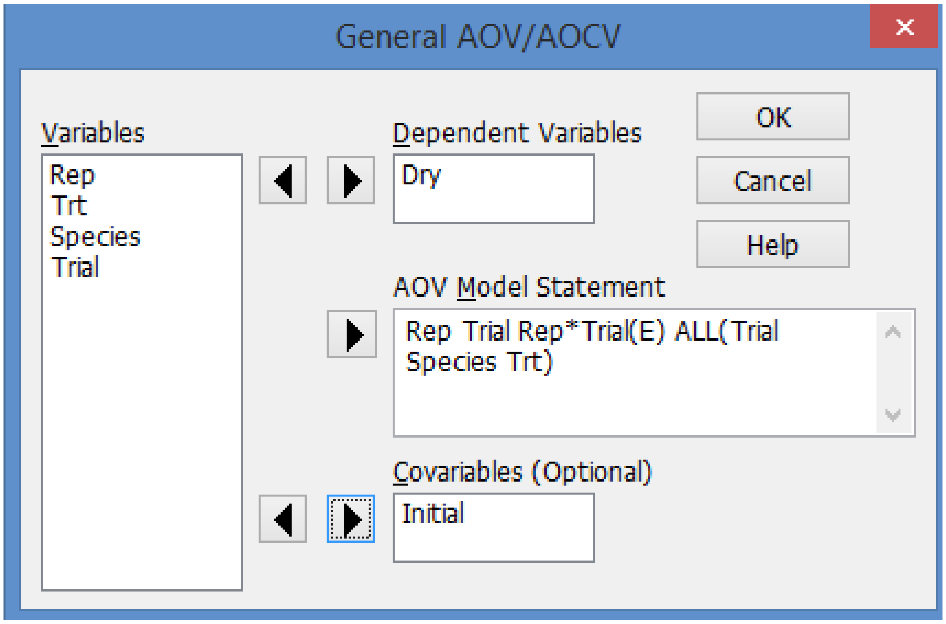
Appendix

Experiment 5. Container grown seashore paspalum and bermudagrass response to ethofumesate, metribuzin, mesotrione, and topramezone alone and in tank mixes at Magoon Research Station. Example of ANOVA model (including a covariant) and table in Statistix® 10.0 (Analytical Software, Tallahassee, FL).



Analysis of Variance Table for Dry Weights of Clippings 21DAS01

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	3	1.2455	0.4152	2.73	0.2159
Trial	1	0.2587	0.2587	1.70	0.2834
Error Rep*Trial	3	0.4567	0.1522		
Species	1	12.7996	12.7996	91.63	0.0000
Trt	9	28.4945	3.1661	22.66	0.0000
Trial*Species	1	0.6508	0.6508	4.66	0.0330
Trial*Trt	9	3.3170	0.3686	2.64	0.0083
Species*Trt	9	6.7198	0.7466	5.34	0.0000
Trial*Species*Trt	9	1.2209	0.1357	0.97	0.4677
Initial	1	2.2118	2.2118	15.83	0.0001
Error Rep*Trial*Species*Trt	113	15.7855	0.1397		
Total	159				